13 • Nautical Cartography and Traditional Navigation in Oceania

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MENTAL CARTOGRAPHY

The navigational practices of Oceanians present somewhat of a puzzle to the student of the history of cartography. Here were superb navigators who sailed their canoes from island to island, spending days or sometimes many weeks out of sight of land, and who found their way without consulting any instruments or charts at sea. Instead, they carried in their head images of the spread of islands over the ocean and envisioned in the mind's eye the bearings from one to the other in terms of a conceptual compass whose points were typically delineated according to the rising and setting of key stars and constellations or the directions from which named winds blow. Within this mental framework of islands and bearings, to guide their canoes to destinations lying over the horizon these navigators applied vital information obtained by watching with the naked eye the stars, ocean swells, steady winds, island-influenced cloud formations, land-nesting birds fishing out at sea, and other cues provided by nature.

Among the few places in the Pacific where traditional navigation is still practiced are several tiny atolls in the Caroline Islands of Micronesia. In his study of traditional Carolinian navigation, anthropologist Thomas Gladwin captured the essence of how at sea a master navigator relies solely on his senses and a mental image of the islands around him. "Everything that really matters in the whole process goes on in his head or through his senses. All he can actually see or feel is the travel of the canoe through the water, the direction of the wind, and the direction of the stars. Everything else depends upon a cognitive map, a map which is both literally geographical and also logical."[1] A number of geographers, psychologists, and other scholars have written about how people form "cognitive maps" or "mental maps" of the world around them.[2] But whereas most of these studies have focused primarily on the general processes by which children and ordinary adults form and utilize images of their surroundings, this chapter explores the highly structured ways professional navigators from the Pacific Islands mentally charted the environment of sea, islands, swells, winds, stars, and other features vital to their art, and then employed these formal images and their own sense perceptions to guide their canoes over the ocean.

The idea of physically portraying their mental images was not alien to these specialists, however. Early Western explorers and missionaries recorded instances of how indigenous navigators, when questioned about the islands surrounding their own, readily produced maps by tracing lines in the sand or arranging pieces of coral. Some of these early visitors drew up charts based on such ephemeral maps or from information their informants supplied by word and gesture on the bearing and distance to the islands they knew.

Furthermore, on some islands master navigators taught their pupils a conceptual "star compass" by laying out coral fragments to signify the rising and setting points of key stars and constellations. Once their pupils had mastered the star compass, they were required to imagine a series of "island charts" by mentally placing successive islands at the center of the compass and then reciting the islands, reefs, and other navigationally important features to be found by sailing along each star bearing. In the Marshall Islands, and only there, navigators skilled at reading the way islands disrupt the patterning of the deep ocean swells made "stick charts" depicting islands and their effect on the swells. These charts were used to teach students and as mnemonic aids to be consulted before a voyage. Yet when these navigators set sail, they did not take with them any such physical representations of islands, star positions, or swell patterns to aid them in their task. A wealth of ethnographic evidence, which began accumulating with the observations of Captain James Cook and other early explorers, in conjunction with contem-

1. Thomas Gladwin, *East Is a Big Bird: Navigation and Logic on Puluwat Atoll* (Cambridge: Harvard University Press, 1970), 195.

2. For example, Peter Gould and Rodney White, *Mental Maps,* 2d ed. (Boston: Allen and Unwin, 1986); Benjamin Kuipers, "The 'Map in the Head' Metaphor," *Environment and Behavior* 14 (1982): 202–20; William Bunge, *Theoretical Geography,* 2d ed. (Lund, Sweden: Gleerup, 1966), 39–52; Dedre Gentner and Albert L. Stevens, eds., *Mental Models* (Hillsdale, N.J.: Lawrence Erlbaum, 1983); Gary L. Allen et al., "Developmental Issues in Cognitive Mapping: The Selection and Utilization of Environmental Landmarks," *Child Development* 50 (1979): 1062–70; and David S. Olton, "Mazes, Maps, and Memory," *American Psychologist* 34 (1979): 583–96.

porary research carried out at sea with the few surviving traditional navigators and with islanders who are now learning this ancient art, indicates how these seafarers mentally charted their oceanic world.

Not surprisingly, standard histories of cartography focused on physical map artifacts have largely ignored the way Oceanic navigators mentally charted the islands, stars, and swells. To be sure, the fascinating stick charts showing how islands disrupt ocean swells have been mentioned in such works.[3] But these devices were used by navigators from only one archipelago and, like other physical representations made by Pacific navigators, were not employed at sea. How these navigators conceptualized the location of islands, set their course toward them, dead reckoned along the way, and then made landfall–all without consulting any physical charts while at sea–has, however, been extensively discussed in the historical and anthropological literature dealing with the colonization of the islands, canoe voyaging, and techniques of navigation.[4] In addition, an effort I initiated in the 1960s to reconstruct ancient voyaging canoes, relearn traditional ways of navigating, and then test these over the long sea routes of Polynesia has further focused interest on this subject.[5] This chapter draws on what we have learned from historical, anthropological, and experimental investigations of Pacific Island navigation to bring this fascinating Oceanic tradition into the discussion of the general development of cartography on our planet.

After introductory remarks on the early European exploration of the region, I examine the first bits of cartographic evidence of indigenous geographical knowledge of Pacific Islanders to be brought to the attention of the Western world. These came in the form of four charts–one from Polynesia and three from Micronesia–drawn by early Western explorers and missionaries based on geographical information supplied by island navigators.

These charts alerted the outside world that these Stone Age navigators could locate considerable numbers of islands within a wide radius of their own. But they did not provide any insights into the way the navigators themselves mapped the islands, ocean swells, star paths, and all the other features of their oceanic environment vital to the practice of their craft. To inquire into indigenous nautical cartography, we must first appreciate the general principles by which these consummate navigators guided their canoes. Following an outline of these principles, this chapter reviews the navigational methods and associated cartographic practices of two distinct, though related, navigational traditions from Micronesia, selected because the documentation on them by far exceeds that available on other Pacific systems. The first, from the Caroline Islands, is an essentially celestial system that involves various ways of mapping the stars and islands, both on the ground and in the mind, and of using the way the bearings among these change throughout a voyage to elegantly chart the progress of a canoe toward its destination. The second, from the Marshall Islands, focuses on the sea rather than the sky. The navigators there took a general Oceanic technique–detecting the presence of an island before it can be seen by the way it disrupts the regular ocean swells–and developed it into a highly sophisticated method for finding their way among the atolls of their archipelago. It was they who made the famous stick charts to represent and teach the way swells are reflected, refracted, and diffracted by islands in their path.

The European Penetration of Remote Oceania

When Magellan made the first known crossing in 1520, he was not just exploring the ocean he christened the Pacific. His goal was to find a new route to the spices grown on the islands scattered off the southeastern tip of Asia. For more than two centuries thereafter, it was primarily the desire to gain access to the riches of Asia that drove Europeans to cross this widest of the world's oceans–not any passion for exploration per se. Even the establishment by the Spanish of annual trading voyages between their possessions in the Philippines and those of the New World added little to the outside world's know-

3. For example, Leo Bagrow, *History of Cartography,* 2d ed., rev. and enl. R. A. Skelton (Chicago: Precedent, 1985), 27–28; Norman J. W. Thrower, *Maps and Civilization: Cartography in Culture and Society* (Chicago: University of Chicago Press, 1996), 4–7; Gordon R. Lewthwaite, "Geographical Knowledge of the Pacific Peoples," in *The Pacific Basin: A History of Its Geographical Exploration,* ed. Herman Ralph Friis (New York: American Geographical Society, 1967), 57–86, esp. 73–74; and Michael Blakemore, "From Way-Finding to Map-Making: The Spatial Information Fields of Aboriginal Peoples," *Progress in Human Geography* 5 (1981): 1–24, esp. 19–20.

4. For example, Jack Golson, ed., *Polynesian Navigation: A Symposium on Andrew Sharp's Theory of Accidental Voyages,* rev. ed. (Wellington: Polynesian Society, 1963); David Lewis, *We, the Navigators: The Ancient Art of Landfinding in the Pacific,* 2d ed., ed. Derek Oulton (Honolulu: University of Hawai'i Press, 1994); Gladwin, *East Is a Big Bird* (note 1); Ward Hunt Goodenough, *Native Astronomy in the Central Carolines* (Philadelphia: University Museum, University of Pennsylvania, 1953); Andrew Sharp, *Ancient Voyagers in the Pacific* (Wellington: Polynesian Society, 1956); and the many entries listed in Nicholas J. Goetzfridt, comp., *Indigenous Navigation and Voyaging in the Pacific: A Reference Guide* (New York: Greenwood Press, 1992).

5. David Lewis, "Ara Moana: Stars of the Sea Road," *Journal of the Institute of Navigation* 17 (1964): 278–88; Will Kyselka, *An Ocean in Mind* (Honolulu: University of Hawai'i Press, 1987); Ben R. Finney, "Rediscovering Polynesian Navigation through Experimental Voyaging," *Journal of Navigation* 46 (1993): 383–94; idem, *Voyage of Rediscovery: A Cultural Odyssey through Polynesia* (Berkeley: University of California Press, 1994); idem, "Voyaging Canoes and the Settlement of Polynesia," *Science* 196 (1977): 1277–85; and idem, "Colonizing an Island World," in *Prehistoric Settlement of the Pacific,* ed. Ward Hunt Goodenough (Philadelphia: American Philosophical Society, 1996), 71–116.

ledge of the Pacific and its peoples. In fact, for more than two centuries galleons sailed across the Polynesian triangle on the leg from Mexican ports to Manila without realizing they were traversing one of the great cultural provinces of the world. The few exploratory voyages into the Pacific during this era could not be called scientific, for their leaders were searching for rich lands thought to lie there. Examples include the attempts in the sixteenth and seventeenth centuries by Alvaro Mendaña de Neira, Pedro Fernández de Quirós, Jakob Le Maire, Willem Schouten, and others to find Terra Australis Incognita, the great continent that cosmographers of that era thought must lie in the southern reaches of the Pacific.[6]

When European navigators did chance upon islands in the middle of the ocean, they were surprised to find that virtually every one was already inhabited. On islands lying thousands of miles out to sea from any continental shore they were perplexed to find thriving populations that had no ships, charts, or navigational instruments. How, wondered these proud navigators from the other side of the world, could people who apparently had none of the equipment essential for deep sea voyaging have reached islands spread over an ocean that, to quote one of Magellan's chroniclers, was "so vast that the human mind can scarcely grasp it"?[7]

Europeans consequently offered a variety of ingenious hypotheses to explain how the islands they found had come to be populated. When, for example, the second Mendaña expedition made landfall in 1595 on the Marquesas Islands some four thousand nautical miles[8] to the west of Peru, the expedition's navigator, Pedro Fernández de Quirós, judged the people there to be "without skill or the possibility of sailing to distant parts."[9] To account for their presence on these remote islands, Quirós posited that just to the south of the Marquesas there must be a long chain of closely spaced islands extending eastward from Asia that had enabled people of such limited technology to penetrate so far into the ocean.[10] Similarly, when on Easter Day 1722 the Dutch navigator Jacob Roggeveen happened across the speck of land he thereby christened Paasch Eylandt (Rapa Nui), he was at such a complete loss to explain how Stone Age people with only small, frail canoes at their disposal could be living on such an isolated island that he proposed they must have been separately created there by God.[11] Even as late as 1772, the French navigator Julien Crozet conjured up a sunken continent to explain how peoples so similar in language and culture could be living on islands strewn two thousand miles across the South Pacific, from Tahiti to Aotearoa (New Zealand). Since they did not seem to have the means to sail long distances, he concluded they must be survivors of a race once spread over a vast continent that subsequently broke up and sank in a tremendous volcanic cataclysm, sparing only those living on mountaintops high enough to remain above sea level and thereby become islands.[12]

The real European discovery of the islands of Remote Oceania did not begin until the dawn in the late eighteenth century of what Goetzmann has called the second great age of discovery.[13] By then better ships and navigational methods, as well as new ideas about nutrition, had made it easier to undertake prolonged voyages of exploration. Of greater importance for our purposes was a new attitude toward exploration. Driven by Enlightenment goals, this was the era when explorers from England, France, and Spain, and later Russia and the United States, sailed the Pacific to chart the islands and study their flora, fauna, and inhabitants as well as to pursue geopolitical goals.

Captain James Cook opened this new era of Pacific exploration with three grand voyages made between 1769 and 1778, during which this quintessential Enlightenment explorer charted scores of islands previously unknown to the outside world. Among other things, he learned enough of the languages and customs of the peoples he encountered to literally discover Polynesia by recognizing that all the peoples living on the islands bounded by Hawai'i, Rapa Nui (Easter Island), and Aotearoa (New Zealand) belonged to the "same nation."[14] On his first voyage, in 1769, Cook was sent by the Admiralty to the island of Tahiti, which had been "discovered" two years before by another British navigator, Samuel Wallis. There his task, which had been formulated by the Royal

6. J. C. Beaglehole, *The Exploration of the Pacific* (London: A. and C. Black, 1934), 69–165.

7. Maximilian Transylvanus, in a letter to the cardinal-archbishop of Salzburg written in 1522, cited in James Cook, *The Journals of Captain James Cook on His Voyages of Discovery,* 4 vols., ed. J. C. Beaglehole, Hakluyt Society, extra ser. nos. 34–37 (London: Hakluyt Society, 1955–74), vol. 4, *The Life of Captain James Cook,* by J. C. Beaglehole, 109 and n. 1.

8. Hereafter, all distances given in miles refer to nautical miles. One nautical mile equals 1.15 statute (land) miles and 1.85 kilometers.

9. *La Austrialia del Espíritu Santo,* 2 vols., trans. and ed. Celsus Kelly, Hakluyt Society, ser. 2, nos. 126–27 (Cambridge: Cambridge University Press, 1966), 2:309.

10. Pedro Fernández de Quirós [Queirós], *The Voyages of Pedro Fernandez de Quiros, 1595 to 1606,* 2 vols., trans. and ed. Clements R. Markham, Hakluyt Society, ser. 2, nos. 14–15 (London: Hakluyt Society, 1904), 1:152.

11. Jacob Roggeveen, *The Journal of Jacob Roggeveen,* ed. Andrew Sharp (Oxford: Clarendon Press, 1970), 101, 153–54.

12. Julien Marie Crozet, *Nouveau voyage à la Mer du Sud,* ed. Alexis Marie de Rochon (Paris: Barrois, 1783), 48 and 153–55.

13. William H. Goetzmann, *New Lands, New Men: America and the Second Great Age of Discovery* (New York: Viking, 1986), 1–5.

14. Ben R. Finney, "James Cook and the European Discovery of Polynesia," in *From Maps to Metaphors: The Pacific World of George Vancouver,* ed. Robin Fisher and Hugh Johnston (Vancouver: University of British Columbia Press, 1993), 19–34, esp. 20.

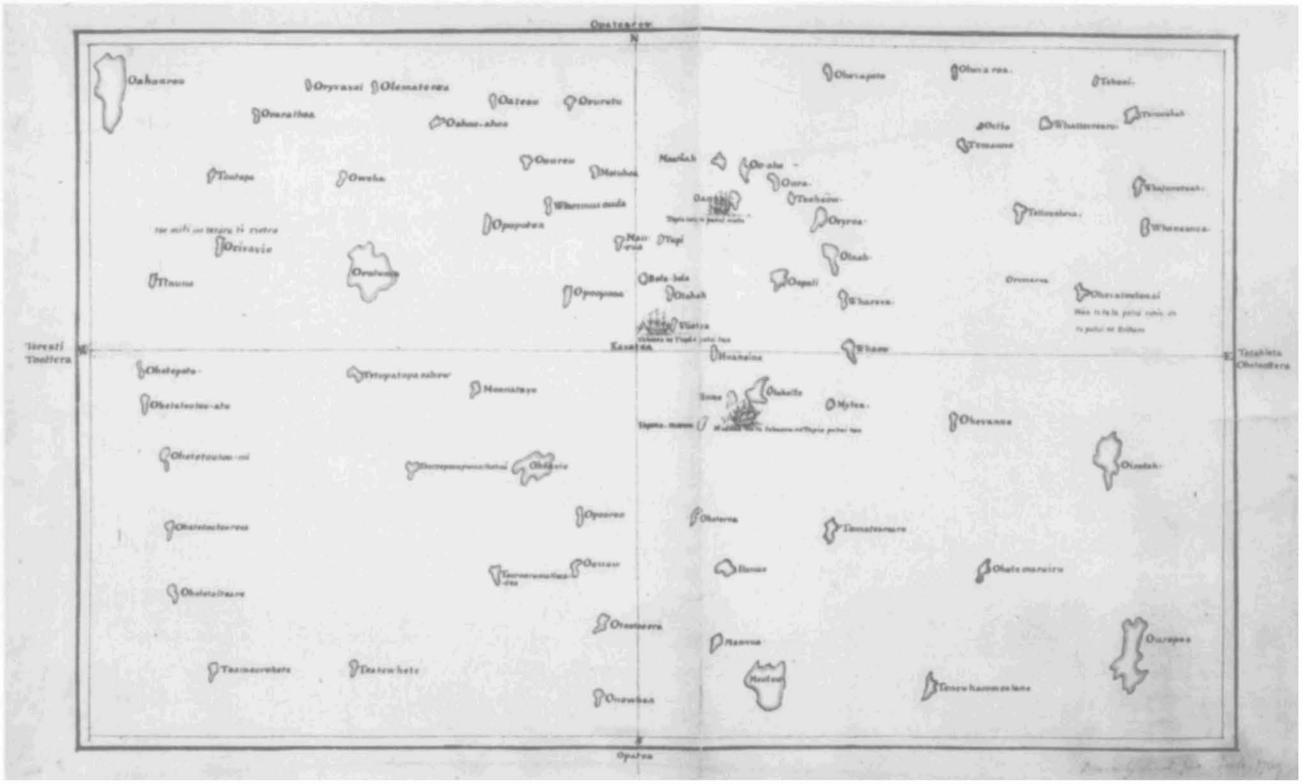


FIG. 13.1. "TUPAIA'S CHART" (COOK VERSION). This chart represents the geographical knowledge of a remarkable Tahitian named Tupaia. It was drafted in 1769 by Lieutenant James Cook during his historic visit to Tahiti and neighboring islands. The chart, which apparently is a copy of a lost original, shows Tahiti at the center with seventy-four islands arranged around it. Many of the islands cannot now be exactly identified, however, and among those that can be identified many were misplaced, apparently because the British did not properly understand Tahitian directional terms. After restoring the islands in question to their proper position, it can arguably be said the chart indicated that Tupaia had a wide, if inexact, knowledge of islands spread over forty degrees of longitude and twenty degrees of latitude, an oceanic realm larger than that of the continental United States.
Size of the original: ca. 21 × 33.5 cm. By permission of the British Library, London (Add. [Banks] 21,593.c).

Society, was to observe the transit of Venus across the face of the sun as part of an international effort to determine the distance between the earth and the sun. Although Cook was not satisfied with the accuracy of his observations, he did become excited by what he learned from the Tahitians about their seafaring skills, the range of their voyaging, and their extensive knowledge of the islands in their part of the Pacific.

Early Charts Drawn by European Explorers and Missionaries

Tupaia's Chart of Polynesia

When Cook reached Tahiti aboard HMS *Endeavour,* he and his chief scientist, the naturalist Joseph Banks, did something virtually without precedent among previous European navigators who ventured into the Pacific. They stayed put for months, made friends with the people, and learned the rudiments of their language. One of their new acquaintances was a man named Tupaia, a priest, adviser to high chiefs, and fount of indigenous knowledge on geography, meteorology, and navigation. Among other things, this Tahitian polymath told Cook about the many islands surrounding Tahiti and described how he and his fellow Tahitians sailed to and from them, sometimes remaining at sea for weeks at a time. Cook admired the Tahitians' canoes and readily accepted the possibility that "these people sail in those seas from Island to Island for several hundred Leagues, the Sun serving them for a compass by day and the Moon and Stars by night." [15] He was therefore predisposed to believe Tupaia and pressed him for more precise geographical information, which he thought might be useful for future explorations of the South Seas. The Tahitian responded by dictating a long

15. Cook, *Journals,* vol. 1, *The Voyage of the Endeavour, 1768–1771,* 154, 291–94 (note 7).

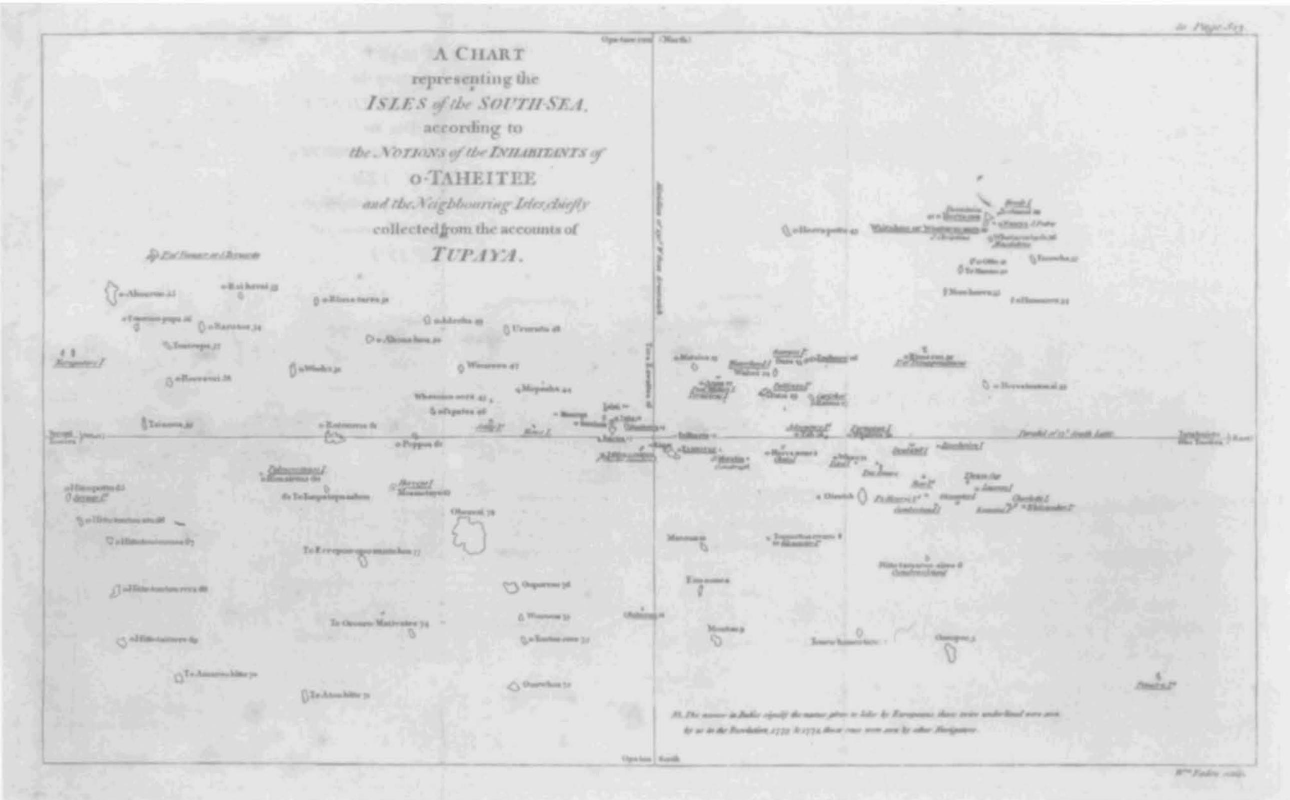


FIG. 13.2. "TUPAIA'S CHART" (FORSTER VERSION). Johann Reinhold Forster, the naturalist on Cook's second expedition to Tahiti, had this version drafted from a copy he received from Lieutenant Pickersgill, who served with Cook on his first Pacific voyage. It differs from Cook's version in the placement, size, and spelling of some islands. Forster also labeled those islands visited by Europeans with their European names.
From Johann Reinhold Forster, *Observations Made during a Voyage Round the World* (London: Robinson, 1778), opp. 513. Photograph courtesy of the Library of Congress, Washington, D.C.

list of islands from which a chart was drawn depicting the location of seventy-four of them relative to Tahiti (fig. 13.1).[16]

This most famous example from the Pacific of a chart drawn by Westerners but based on indigenous geographical knowledge has been widely discussed over the past two centuries because it arguably indicates that Tahitians knew about islands spread over more than forty degrees of longitude and twenty degrees of latitude–an oceanic realm larger than the continental United States. This, however, is a liberal reading of the chart, for there are many problems with the identification and placement of the islands depicted, particularly those more than a few hundred miles from Tahiti, raising serious questions about the quality of Tupaia's geographical knowledge as well as the process by which his mental map of the islands surrounding Tahiti was transferred onto paper.

It is not even clear who drew the original chart, which apparently has not survived. Cook wrote in his journal about a chart that had been "drawn by Tupia's [Tupaia's] own hands," yet the earliest version of it that survives today bears the legend "Drawn by Lieut. James Cook 1769."[17] Johann Forster, the naturalist on Cook's second voyage into the Pacific who took a great interest in the chart and its Tahitian source, published an entirely different account of how the chart was drawn. He reported that after Tupaia had "perceived the meaning and use of charts, he gave directions for making one according to his account, and always pointed to the part of the heavens, where each isle was situated, mentioning at the same time that it was either larger or smaller than Taheitee, and likewise whether it was high or low, whether it was peopled or not, adding now and then some curious accounts relative to some of them."[18] Unfortunately, Forster neglected to specify who did the drawing.

16. Cook, *Journals*, vol. 1, *The Voyage of the Endeavour, 1768–1771*, 291–94.

17. Cook, *Journals*, vol. 1, *The Voyage of the Endeavour, 1768–1771*, 293–94 and n. 1, and James Cook, *The Journals of Captain James Cook on His Voyages of Discovery: Charts and Views Drawn by Cook and His Officers and Reproduced from the Original Manuscripts*, ed. R. A. Skelton (Cambridge: Cambridge University Press, 1955), viii, chart XI.

18. Johann Reinhold Forster, *Observations Made during a Voyage Round the World* (London: Robinson, 1778), 511.

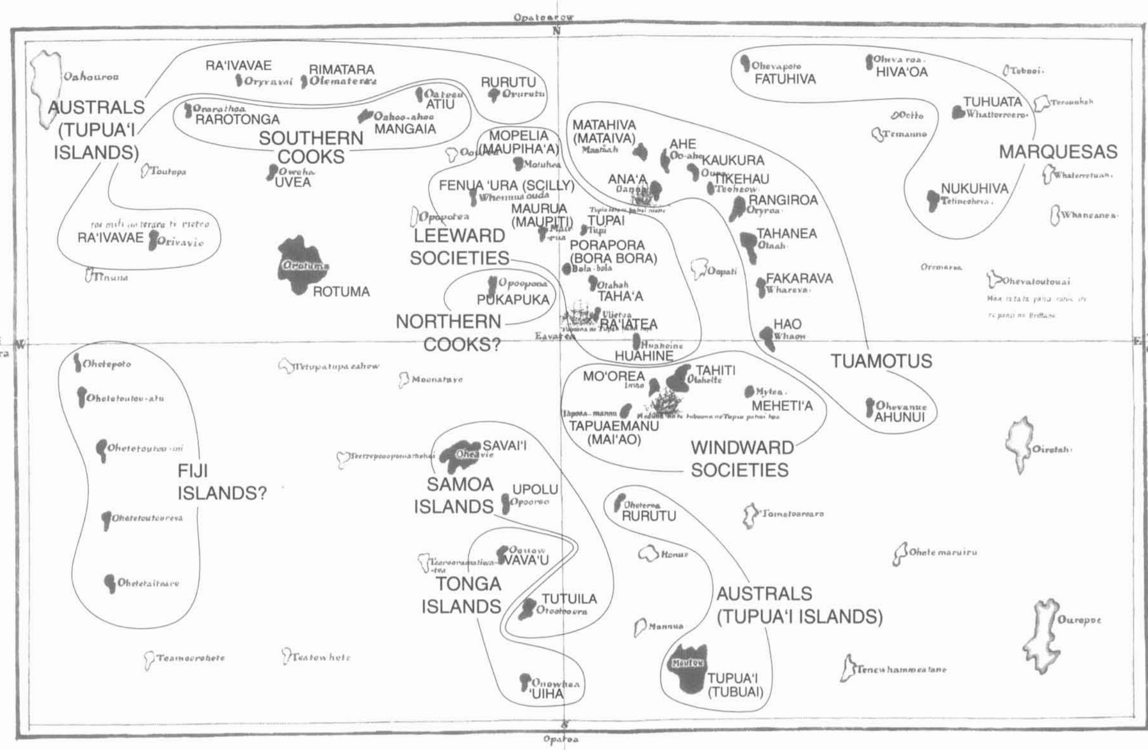


FIG. 13.3. IDENTIFIED ISLANDS ON COOK'S VERSION OF "TUPAIA'S CHART" AND THEIR GROUPING BY ARCHIPELAGO. The islands that can be identified with varying degrees of certainty are shaded and labeled in block letters with their current names. Problems with Cook's spelling of the island names dictated to him by Tupaia, along with Tupaia's apparent use of archaic or alternative names for many islands, makes it difficult to identify more than about forty-five of the seventy-four islands on Tupaia's chart. Grouping the identified islands by archipelago, and then comparing their placement with the actual distribution of islands and archipelagoes (fig. 13.4), shows that many of the islands unknown to Europeans were misplaced on the chart, perhaps because the English misunderstood the Tahitian words for south and north and reversed them in drawing the chart and interpreting Tupaia's directions.

Whatever the case, until the publication in 1955 of Cook's version, discussion of Tupaia's chart primarily revolved around an apparently third-generation copy published by Forster in 1778 (fig. 13.2).[19] The naturalist reported that he had it engraved from a copy of the original chart, which had been lent to him by Lieutenant Richard Pickersgill, an officer from Cook's first Pacific voyage. He also wrote that he had compared Pickersgill's copy with another copy held by Banks and found that the two differed only in a few details. The second copy consulted was almost certainly the one drawn by Captain Cook himself, for we know that after their voyage Banks kept Cook's version, and that on Banks's death it was transferred to the British Museum, where it lay buried for a century and a half.

After the publication of Forster's engraving, Tupaia's chart was generally viewed as evidence of far-ranging indigenous geographical knowledge, an interpretation made credible by tales told about his navigational feats. The Tahitian joined the *Endeavour* for the return to England at the invitation of Banks, who apparently wanted to learn more about his extensive knowledge of geography, astronomy, and navigation as well as (one suspects from reading Banks's journal) to introduce him to London society as a native savant. After leaving Tahiti, Tupaia piloted the *Endeavour* through the leeward Society Islands just to the west-northwest of Tahiti and then on to Rurutu, a small volcanic island three hundred miles to the south.[20] Tupaia gained further fame among his Eng-

19. However, some Continental scholars writing in German followed still another third-generation copy, a crude one made by Johann Forster's son George, in which the Tuamotu and Marquesas Islands have been left out in order to include a detailed legend in the upper right quadrant. See, for example, Richard Andree, *Ethnographische Parallelen und Vergleiche* (Stuttgart: J. Maier, 1878), 207, and Bruno F. Adler, "Karty pervobytnykh narodov" (Maps of primitive peoples), *Izvestiya Imperatorskago Obshchestva Lyubiteley Yestestvoznanya, Antropologii i Etnografii: Trudy Geograficheskago Otdeliniya* (Proceedings of the Imperial Society of the Devotees of National Sciences, Anthropology, Ethnography: Transactions of the Division of Geography) 119, no. 2 (1910), 195–96.

20. Cook, *Journals*, vol. 1, *The Voyage of the Endeavour, 1768–1771*, 140–57 (note 7), and Joseph Banks, *The Endeavour Journal of Joseph Banks, 1768–1771*, 2 vols., ed. J. C. Beaglehole (Sydney: Angus and Robertson, 1962), 1:312–33.

FIG. 13.4. MODERN MAP OF THE REGION COVERED BY TUPAIA'S CHART. Only those islands that can be identified on Tupaia's chart with some certainty are labeled.

lish hosts by demonstrating his dead reckoning skills during the long voyage across the Pacific to Aotearoa (New Zealand), around Australia, and then to Java. Whenever they asked him to indicate the bearing back to Tahiti, to their astonishment they found on checking their compass and charts that he "could always point out the direction in which Taheitee was situated" no matter what had been the twists and turns of the ship's track.[21]

But the Tahitian expert never reached England. Tupaia, who had not been well during the voyage, fell seriously ill and died while the *Endeavour* was in dry dock in the pestilential port of Batavia (now Jakarta). Although Banks had not fully plumbed the depths of his colleague's knowledge, Forster's engraving of Tupaia's chart and the accounts cited above of his navigational skills were enough to establish respect in European scientific circles for Tahitian geographical knowledge and navigational skill. Yet as Western explorers began to fill in the blank spaces of their own charts of the Pacific with islands precisely fixed in terms of latitude and longitude, it became obvious that although some of the readily identifiable islands on Forster's version of Tupaia's chart seemed to be located more or less correctly in relation to Tahiti, others were drawn far from their true positions. There then followed a long succession of attempts to make sense of this enigmatic chart by attempting to decipher more of the island names and to explain why so many islands were not placed where they should be on the chart.[22]

Deciphering Cook's transcriptions of island names is made easier by first stripping away the initial O from many of them, for it simply means "it is." Then Cook's often atrocious renderings of what Tupaia told him have to be converted into the more phonetic spellings used today. Following these steps, Cook's "Otaheite" is easily identified as Tahiti. Yet many islands remain unidentified even after making such orthographic conversions–perhaps because Tupaia often used archaic Tahitian titles for distant islands that are now known by entirely different names. Thus it is possible to identify, and just tentatively in a good number of cases, only about forty-five of the seventy-four islands on the chart (fig. 13.3). Grouping these by archipelago makes it clear that something is very wrong with the chart. Whereas some islands are more or less correctly placed in relation to Tahiti, others have somehow drifted far from where they should lie (see fig. 13.4). The person who made the most sense of this confusion was Horatio Hale, a young philologist on the United States Exploring Expedition, which cruised the Pacific from 1838 to 1842 and spent considerable time at Tahiti. To Hale, the key was to be found in the Tahitian directional terms printed at the top and bottom of Forster's chart (and Cook's as well, though Hale had no way of knowing that): *opatoarow* and *opatoa,* which can be written more phonetically as *apato'erau* and *apato'a.* Hale contended that Cook and his colleagues, who had only a rudimentary knowledge of Tahitian, assumed that since *to'erau* signified the north or northwest wind and *to'a* the wind from the south, *apato'erau* must mean north and *apato'a* south. Hale claimed the reverse.

21. Forster, *Observations,* 509, 531 (note 18).

22. Of the many attempts to make sense of Tupaia's chart and the list of islands he dictated to Cook, among the best are Greg M. Dening, "The Geographical Knowledge of the Polynesians and the Nature of Inter-island Contact," in *Polynesian Navigation: A Symposium on Andrew Sharp's Theory of Accidental Voyages,* ed. Jack Golson, rev. ed. (Wellington: Polynesian Society, 1963), 102–53, and Gordon R. Lewthwaite, "The Puzzle of Tupaia's Map," *New Zealand Geographer* 26 (1970): 1–19. The following analysis leans heavily on these two papers.

Apato'erau signifies south, the point toward which the north wind blows, while *apato'a* refers to north, the point toward which the south wind blows.[23] He further proposed that with this reversal of north and south firmly fixed in their minds, Cook, Banks, and Pickersgill then "overlooked Tupaia while he was drawing, and suggested corrections, which his idea of their superior knowledge induced him to receive against his own convictions."[24]

Following Hale's scenario, imagine the confusion in the *Endeavour*'s great cabin. Tupaia has grasped the meaning of the nautical charts he has seen and probably is as eager to transfer his knowledge of the islands onto paper as the British are to have this valuable information charted. Cook places a sheet of drawing paper on his chart table and along the upper border carefully prints the word *opatoarow,* which he mistakenly thinks means north, and also prints *opatoa* along the lower border on the equally false assumption that it stands for south. (The Tahitian phrases at the right and left edges of the chart appear to correctly designate east and west with terms for sunrise and sunset.) Tupaia then draws Tahiti in the center, after which he starts marking out the islands around it, giving the name of each, its distance in sailing days, and its bearing both verbally and by pointing in the appropriate direction. (Or, following Forster's assertion that Tupaia did not draw the chart, the Tahitian gives these directions to a draftsman who then draws the islands on the chart.) The British, laboring under their reversal of crucial Tahitian directional terms, then force many islands to be shifted either to the north or south of where Tupaia envisions them to lie. The Tahitian expert, who from his long service to high chiefs must have learned when to defer to authority, unfortunately goes along with this cartographic malpractice, allowing, for example, islands in the Australs and Cooks, which are actually to the south and southwest of Tahiti, to be placed to the northwest and, conversely, islands of the Samoan and Tongan groups to be shifted well south of their actual locations. The only islands that the British allow to be drawn in correct relation to Tahiti are those they are already acquainted with from their own voyage and those of previous European navigators–notably those in the leeward Societies, northern Tuamotus, and the Marquesas group.

However, even if we compensate for the directional confusion Hale postulates, it is apparent that the quality of Tupaia's geographical knowledge falls off markedly with increasing distance. Since Tupaia was born on Ra'iatea in the leeward Societies and spent much of his life on Tahiti, it is not surprising that all the islands of the Society group appear on the chart in more or less correct relation to one another. Coverage of the nearby northeast Tuamotus is next best, which is consonant with evidence from the European contact era of frequent trading back and forth between there and Tahiti. Coverage of the next most distant islands, those ranging from about 300 to 750 miles from Tahiti (the southeastern Tuamotus, Marquesas, and the Cook Islands) is much patchier, and that of the islands at the western end of the chart (Samoa, Tonga, Rotuma, and Fiji) can at best be described as very sketchy, which is understandable since these lie 1,200 to 1,700 miles from the Societies.

One of the main unresolved issues concerns the source of Tupaia's knowledge of islands more than three hundred miles or so from Tahiti, particularly the most distant ones at the western end of his chart. Did it reflect information gained from active voyaging to and from them by Tahitian sailors, or was it derived passively from ancient legends and the more recent testimony of castaways from these islands who, after being lost at sea because of navigational error or stormy weather, had accidentally drifted onto Tahitian shores?

Key to resolving the issue is an analysis of a conversation Tupaia and Cook had on board the *Endeavour.* As the ship left the leeward Societies, Cook headed south to take up the second task the Admiralty had given him: the search for the continent many theoreticians thought must lie in the temperate latitudes of the South Pacific. According to Cook's own words, "Tupia" (as he spelled Tupaia's name) objected to this southward course:

> Since we have left Ulietea [Ra'iatea] Tupia hath been very disireous for us to steer to the westward and tells us that if we will but go that way we shall meet with plenty of Islands, the most of them he himself hath been at and from the description he gives of two of them they must be those discover'd by Captain Wallice [Samuel Wallis, the captain of the first European ship to reach Tahiti] and by him call'd Boscawen and Kepple Islands, and these do not lay less than 400 Leagues to the westward of Ulietea; he says that they are 10 or 12 days in going thither and 30 or more in coming back and that their Paheas [from *pahi,* Tahitian for voyaging canoe], that is their large Proes [from *prahu,* a Malay word for sailing canoe] sails much faster then this Ship; all this I beleive to be true and therefore they may with ease sail 40 Leagues a day or more.[25]

Considering the wind conditions prevailing across Polynesia and the sailing characteristics of voyaging ca-

23. The authoritative missionary dictionary by John Davies, *A Tahitian and English Dictionary* (Tahiti: London Missionary Society's Press, 1851), 28, followed Hale's definitions. However, later dictionaries have defined *apato'erau* and *apato'a* as Cook implicitly did.

24. Horatio Hale, *Ethnography and Philology: United States Exploring Expedition, 1838–42* (Philadelphia: Lea and Blanchard, 1846), 122–24. Despite his interpretive breakthrough, Hale did not attempt to redraw Tupaia's chart and instead simply reproduced Forster's engraving.

25. Cook, *Journals,* vol. 1, *The Voyage of the Endeavour, 1768–1771,* 156–57 (note 7).

noes, as recently determined through extensive sea trials my colleagues and I conducted throughout Polynesia with the reconstructed double canoe *Hōkūle'a,*[26] the estimates given by Tupaia for sailing to the "plenty of Islands" lying to the west and then back again point clearly to round-trip voyages made between the Society Islands and West Polynesia. This region lies 1,200 to 1,600 miles west of the Societies and is composed of the archipelagoes of Samoa, Tonga, and eastern Fiji and a number of outlying islands, including the two cited by Cook, Boscawen and Kepple (Tafahi and Niuatoputapu), which are along the northern fringe of the Tonga group.[27]

Tupaia's statement that it took thirty days or more to sail back to the Societies also makes good sense, for the return must be made against the direction whence the trade winds usually blow. As much as Cook admired the graceful lines and workmanship of the Tahitian voyaging canoes, he apparently realized that tacking them long distances against the easterly trade winds and accompanying ocean currents would have been impractical.[28]

Cook was evidently puzzled by this problem until Tupaia told him that Tahitian sailors avoided such long windward passages by waiting for austral summer when the trade winds are frequently interrupted by westerly winds favorable for sailing to the east, then exploiting these wind shifts to work their way home.[29] Because these westerlies are typically episodic, however, occurring in brief spells as troughs of low pressure moving eastward and interrupting the trade wind flow, canoe voyagers probably could not normally have made it from West Polynesia to the Societies in one jump. It is likely that earlier eastbound voyagers usually had to combine favorable winds from at least two spells of westerlies, taking shelter at an intervening island or tacking as best they could whenever the trade winds resumed.[30] This waiting for and then exploiting successive spells of westerlies could easily have taken the thirty days or more that Tupaia said were needed to return from the western islands to the Societies.

Had Tupaia recovered from the illness that struck him at Batavia and reached England, where Banks, Cook, or other interested parties from the *Endeavour* who had learned Tahitian could have talked with him at length, further light might have been shed on this and other issues concerning his chart. Furthermore, it might also have been possible to learn more about how Tahitians envisioned the island field where they voyaged and how they applied that knowledge in navigation. But that was not to be, and unfortunately, on subsequent voyages into the Pacific neither Cook nor his accompanying scientists made the acquaintance of another learned Polynesian like Tupaia who could have filled in the missing information. Then, with the devastating mortality from imported diseases, the disruptions wrought by foreign traders and colonial occupation, and the subsequent adoption by the surviving islanders of Western sailing vessels, the magnetic compass, and other nautical instruments, the practice of indigenous navigation disappeared so quickly in the Society Islands and other parts of Polynesia that it was essentially gone before it could be fully recorded. As a result, instead of a holistic picture of how Polynesians charted their island world and navigated within it, we have only bits and pieces, such as the tantalizing ones Tupaia provided.

EARLY EUROPEAN CHARTS OF THE CAROLINE ISLANDS

The first European charts of Micronesia's Caroline Islands, like the one derived from Tupaia's chart, were based on indigenous geographical knowledge. Following Magellan's traverse of the Pacific in 1520, Spain colonized the Philippines and later established an outpost in Micronesia's Mariana Islands to provide a stop for the galleons sailing between Mexico and the Philippines. Not until well into the nineteenth century, however, did Spain begin to pay attention to the Caroline Islands, the long chain to the south of the Marianas.

Even before this period, the arrival along the eastern shores of the Philippines of Carolinian canoes driven there by storms or long spells of strong trade winds ex-

26. *Hōkūle'a* (Hawaiian for the star Arcturus) is a reconstruction of a twin-hulled Polynesian voyaging canoe that measures sixty-two feet in length and is powered by two Polynesian sprit sails. Since 1975 we have sailed her over seventy-five thousand miles throughout Polynesia, navigating most of that distance by traditional, noninstrument methods (Finney, *Voyage of Rediscovery,* and idem, "Colonizing an Island World" [both note 5]).

27. Although we have not sailed *Hōkūle'a* from the Societies to West Polynesia, our experiments have shown that a double canoe such as the Tahitian *pahi* Cook mentioned can easily make forty leagues or 127 nautical miles a day sailing before the trade winds (using a conversion of 3.18 nautical miles for one marine league; see Peter Kemp, ed., *The Oxford Companion to Ships and the Sea* [Oxford: Oxford University Press, 1976], 472). Sailing ten to twelve days westward before the trades at this rate would take a canoe 1,275 to 1,525 miles to the west, putting it in the midst of West Polynesia.

28. As documented through our extensive sea trials with *Hōkūle'a,* double canoes can certainly sail to windward, but lacking deep keels or centerboards, they do so at a much more modest angle than today's racing yachts. Canoes making long, oblique tacks at seventy-five degrees to the wind must sail almost four miles to make one mile directly to windward. This slow tacking process, along with fighting against the currents that typically accompany steady trade winds, would greatly lengthen time spent at sea on crossings made directly to windward. Particularly when we also consider the battering the canoes and those on board them would receive while constantly bashing through the drenching head seas raised by steady trades, it is difficult to imagine canoe voyagers tacking from West Polynesia all the way back to the Societies.

29. Cook, *Journals,* vol. 1, *The Voyage of the Endeavour, 1768–1771,* 154 n. 2 (note 7).

30. As was the case when sailing *Hōkūle'a* eastward from Samoa to Tahiti in 1986; Finney, *Voyage of Rediscovery,* 125–62 (note 5).

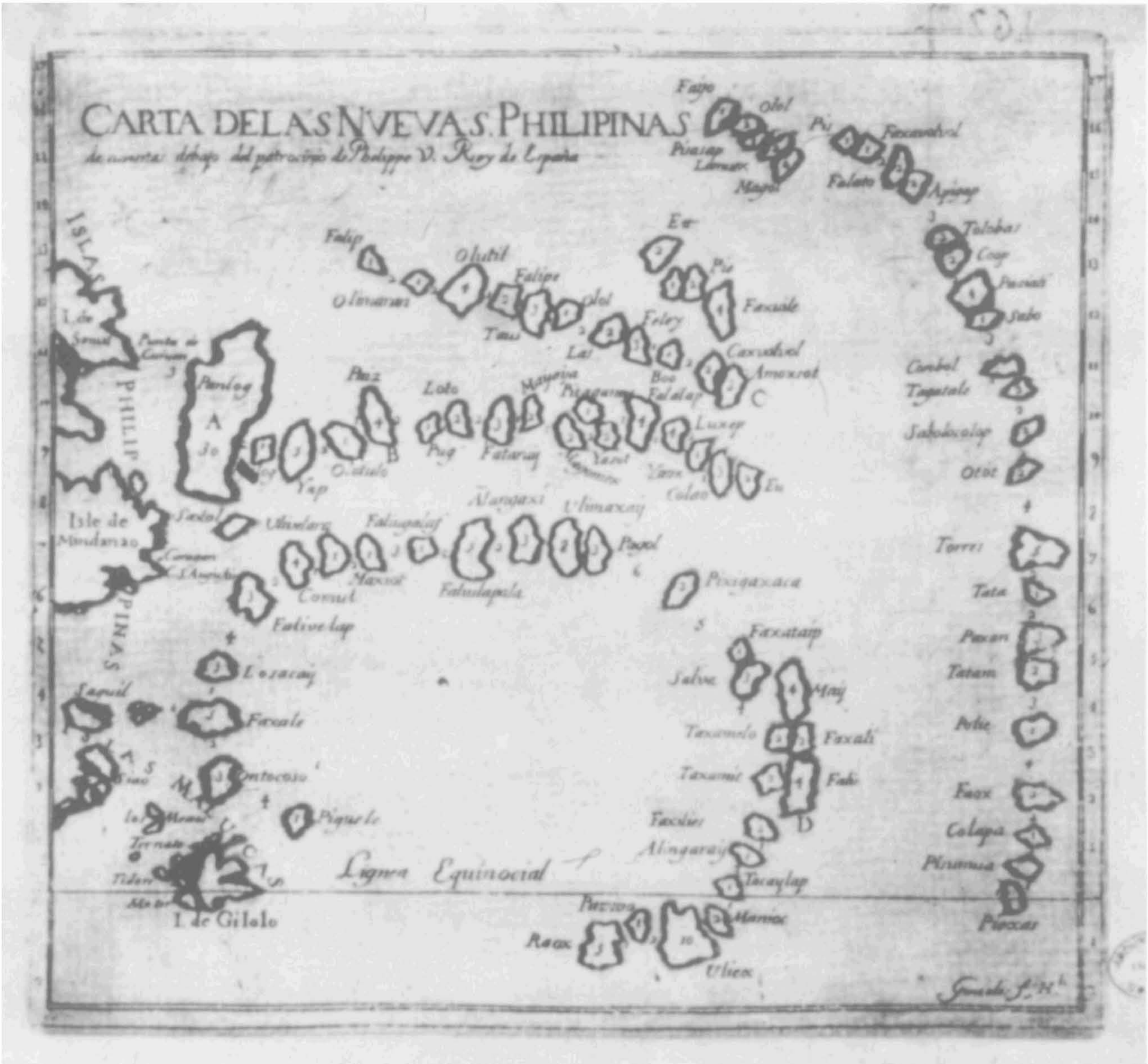


FIG. 13.5. FATHER PAUL KLEIN'S 1696 MAP OF CAROLINE ISLANDS. "Carta de las Nuevas Philipinas [Palaos], descubiertas debajo del patrocinio de Phelippe V, Rey de España." This map, showing the Caroline Islands and other islands east and southeast of the Philippines, was derived from information provided by castaways from Fais Atoll in the Carolines who had landed on Samar Island in the Philippines. The result is not very realistic. Panlog is apparently Belau (Palau) but is drawn as one large island instead of a group of closely spaced islands and is placed far too close to the Philippines. Although the line of islands immediately to the east of Panlog might be said to depict the linear character of the Carolines, the island arcs farther to the east and to the southeast may reflect the way Caroline Islanders charted islands around a central referent.
Size of the original: 18.7 × 20.4 cm. Photograph courtesy of the Ministero de Cultura, Archivo General de Indias, Seville (Mapas y Planos, Filipinas 15).

cited the missionary ambitions of Jesuits stationed there. In December 1696 two strange-looking canoes landed on Samar, an island in the eastern Philippines. To communicate with the castaways the villagers summoned two women who had themselves drifted to Samar some time earlier. By a stroke of fortune, several of the castaways recognized one of the women as their relative, and communication between the Filipinos and the castaways was established. In the resultant conversations, it was learned that the strangers had been blown off course in sailing from Lamotrek to Fais, two small atolls in the Carolines, and had drifted for seventy days before making landfall on Samar. They also named the thirty-two islands that made up their "nation" and later spread out pebbles on the beach to signify the locations of eighty-seven islands they claimed to have visited.[31]

Father Paul Klein, who visited Samar after the arrival of the canoes, took a lively interest in the story and had a chart of the islands drawn from a sketch of the pebble map. Klein then sent the chart and accompanying report about the castaways' homeland to the superior general of the Jesuits in Rome, after which these documents were published in a number of works (fig. 13.5).[32] The long arc of islands aligned north and south and flanked to the southeast by a partial circle of islands may have reflected the way Carolinian navigators visualize the bearings of islands arrayed around a central reference point (to be discussed below), but it probably mystified Western navigators on subsequent missionary expeditions.

Another chart of the Carolines was drawn in 1721 by Jesuit missionary Juan Antonio Cantova when he was stationed on Guam (fig. 13.6). Cantova was aware of the unsuccessful missionary attempts in islands lying due east of the Philippines, which had been stimulated by the reports by Klein and others of castaways from there. He also realized that for missionary success in Las Islas Carolinas, as the islands had recently become known, a better chart of the islands and more accurate descriptions of the customs of the people were needed. Accordingly, when two Carolinian canoes landed on Guam, Cantova made a concerted effort to befriend the people, learn their language and customs, and chart their islands from the testimony given him by the canoes' navigators. The resultant brief ethnography has been called "the best account of Carolinian people until well into the nineteenth century," and the chart, in its own idiom of showing some of the islands in exaggerated size, is a fair representation of the way the Caroline Islands are spread out from west to east for more than a thousand miles (fig. 13.7).[33]

KOTZEBUE'S CHART OF THE MARSHALL ISLANDS

As a great admirer of Cook, the Russian explorer Otto von Kotzebue had no doubt been stimulated by the British navigator's work with Tupaia to attempt to gather similar geographical information from indigenous experts elsewhere in the Pacific. Kotzebue had his chance while visiting Ratak, the eastern chain of the Marshall Islands, for two and a half months in 1817. There he worked at learning the language and took every opportunity to quiz the people about what they knew of other islands in the region. In his journal, Kotzebue enthusiastically describes how, at his request, the Marshallese readily converted their knowledge of the size, shape, and distribution of the islands in this group into ephemeral charts of some accuracy. For example, after a month on Wotje Atoll, the Russian captain managed to get Lagediack, an experienced navigator, to outline in the sand the entire Ratak chain. First Lagediack drew a circle and placed small lumps of coral around it to represent the atoll outline of Wotje and its constituent islets. Then he outlined in the sand all the atolls of the Ratak chain extending to the north and south of Wotje, using still more coral fragments to represent the islets around the perimeter of each atoll.[34]

The excited Kotzebue then set sail to find these islands. After easily locating several of them, the Russian astonished a chief on Maloelap Atoll by sketching the entire chain in the sand and reciting the names of each island as given to him by his Wotje informant. The chief found the alignment to be not quite right, however, and outlined in the sand his own mental map, which according to Kotzebue later proved, in the light of his own survey, to be "very correct."[35]

At another atoll, Kotzebue met Langemui, an elderly man with numerous scars on his body, which he said were from wounds inflicted by the inhabitants of Ralik. When the Russian finally realized that Ralik was another chain of islands lying immediately to the west of and parallel to the Ratak chain, he prevailed on the old man to give more information. This Langemui did by outlining with coral fragments placed on a mat first the Ratak chain and then the Ralik chain. To show the distances between islands, he took another small piece of coral and used it to figuratively "sail" across the Ratak chain, then from the Ratak to the Ralik chain, and finally between the islands of the latter, noting the distances involved in sailing days or portions thereof. Given the problems Kotzebue must have had translating such rough outlines of islands and measures of sailing time to a chart on a Mercator projec-

31. Francis X. Hezel, *The First Taint of Civilization: A History of the Caroline and Marshall Islands in Pre-colonial Days, 1521–1885* (Honolulu: University of Hawai'i Press, 1983), 36–37.

32. "Lettre écrite de Manille le 10. de juin 1697 par le Père Paul Clain de la Compagnie de Jésus au Révérend Père Thyrse Gonzalez, Général de la même Compagnie," in *Lettres édifiantes et curieuses, écrites des missions étrangères, par quelques missionnaires de la Compagnie de Jésus,* 34 vols. (Paris, 1702–76), 1:112–36; Glynn Barratt, *Carolinean Contacts with the Islands of the Marianas: The European Record* (Saipan: Micronesian Archaeological Survey, 1988), 17–20; and Hezel, *First Taint,* 36–40.

33. Hezel, *First Taint,* 48–55, quotation on 50, and Barratt, *Carolinean Contacts,* 20–23. For Cantova's account, see "Lettre du P. Jean Antoine Cantova, missionnaire . . . au R. P. Guillaume Daubenton . . . 20 de mars 1722," in *Lettres édifiantes et curieuses, écrites des missions étrangères, par quelques missionnaires de la Compagnie de Jésus,* 34 vols. (Paris, 1702–76), 18:188–247.

34. Otto von Kotzebue, *A Voyage of Discovery into the South Sea and Beering's Straits . . . in the Years 1815–1818,* 3 vols., trans. H. E. Lloyd (London: Longman, Hurst, Rees, Orme, and Brown, 1821), 2:83–84.

35. Kotzebue, *Voyage of Discovery,* 2:108–9.

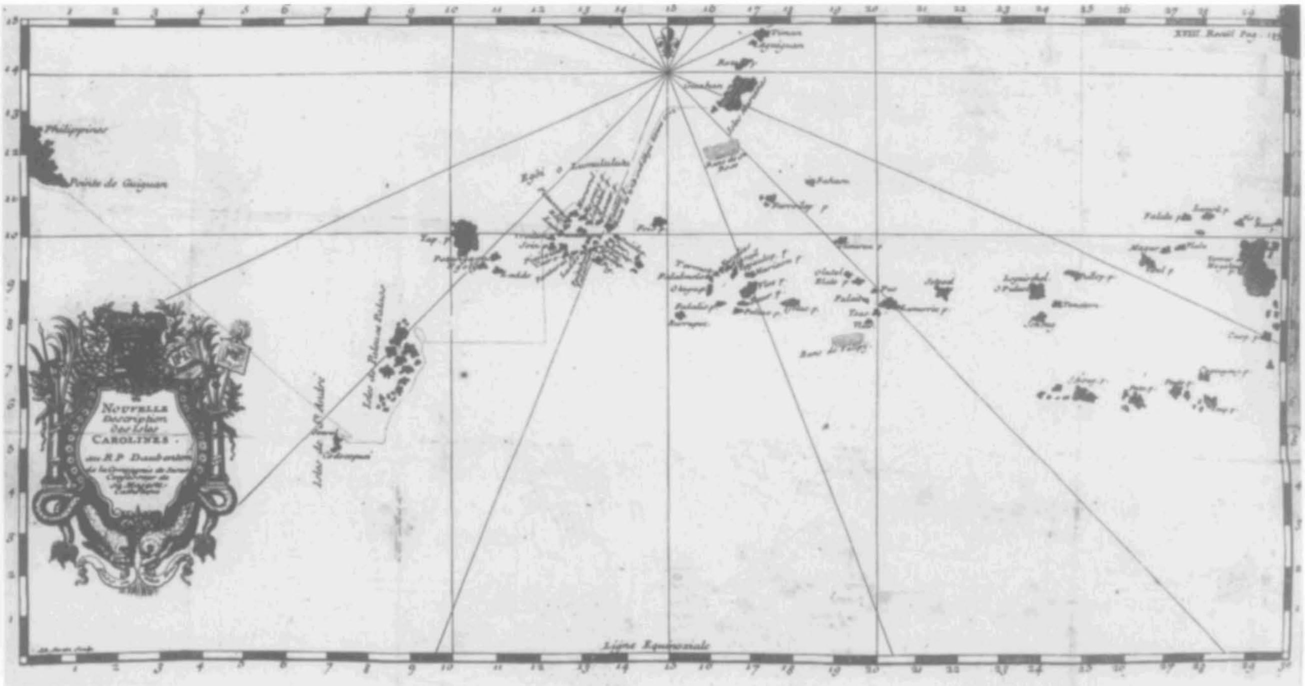


FIG. 13.6. CANTOVA'S CHART OF THE CAROLINE ISLANDS OF MICRONESIA. In 1722 Juan Antonio Cantova, a Jesuit missionary stationed in the Mariana Islands of Micronesia, drafted the original of this published chart from information given him by castaways from the Caroline Islands, a long chain of atolls and a few high islands that lie several hundreds of miles to the south of the Marianas. The chart shows that portion of the Carolines known to the castaways from sailing experience: from Belau (labeled "Islas de Palau ou Palaos") and Uap (Yap) in the west to Chuuk (Truk), the large island on the eastern border, which is unnamed except for its western point (labeled "Torres ou Hogolen P").
From "Lettre du P. Jean Antoine Cantova, missionnaire . . . au R. P. Guillaume Daubenton . . . 20 de mars 1722," in *Lettres édifiantes et curieuses, écrites des missions étrangères, par quelques missionnaires de la Compagnie de Jésus,* 34 vols. (Paris, 1702–76), vol. 18, facing 189.

tion, the general correspondence is striking between Kotzebue's chart (fig. 13.8) and one drawn from the corresponding section of a modern hydrographic chart (fig. 13.9). Note, however, that although the placement of the islands of the Ralik chain depended solely on Langemui's testimony, that of the islands in the Ratak chain was based on both indigenous testimony and Kotzebue's own survey of several of the chain's islands and his astronomical determination of their latitude and longitude.[36]

An Outline of Oceanic Navigation and Cartography

What lay behind the geographical knowledge derived from Tupaia and his Carolinian and Marshallese counterparts and used to construct the charts considered in the previous section was not seriously investigated by their interlocutors, not even by Cook. Nor did any of the other early Western explorers and missionaries inquire closely into how island navigators charted the islands and archipelagoes of their world and navigated between them. (Alternatively, if some did make thorough inquiries, they never published the results.) Not until the late 1800s and early 1900s did foreign scholars begin to investigate this field of indigenous knowledge. Although by then it was too late to get much firsthand information from Polynesia, the situation was very different in the less affected islands of Micronesia. There, notably among the atolls of the Marshall and Caroline Islands, the canoe makers kept building sailing canoes and navigators continued sailing them from island to island well into the twentieth century, and those from a few atolls in the central Carolines are still doing so. Consequently we now have much fuller accounts of traditional navigation and associated cartographic practices from these two archipelagoes than from anywhere else in Oceania.

36. Kotzebue, *Voyage of Discovery,* 2:143–46 (note 34). While in the Marshalls Kotzebue befriended a pair of castaways from the Caroline Islands, Edock and Kadu, who told him and Chamisso, the naturalist on the Russian expedition, much about their home island of Woleai and the islands surrounding it. Based on verbal directions primarily from Edock, Kotzebue drew another reasonably accurate chart (except for the exaggerated size of the islands), in this case of the Caroline Islands from Belau in the east to Truk in the west. Since Kotzebue had at his disposal the chart made earlier by Cantova, however, his effort may not have been totally based on Edock's testimony (2:132–33, with the chart inserted at the back of volume 2).

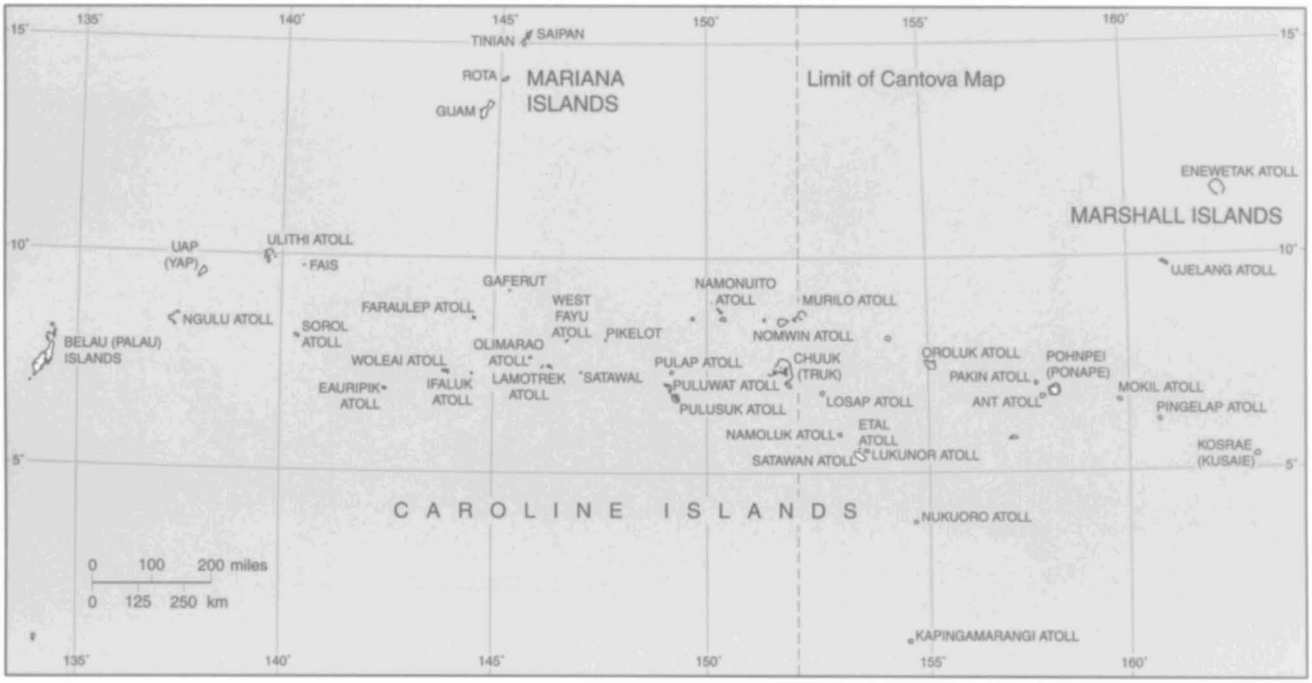


FIG. 13.7. THE CAROLINE ISLANDS. This modern map shows the Caroline Islands stretching west to east from Belau (Palau) and its outliers to Kosrae (Kusaie). A comparison of this chart with Cantova's chart indicates that although the castaways had a good idea of the general configuration of the islands lying between Belau and Chuuk (Truk), some islands–notably Belau, Uap (Yap), and Chuuk–are greatly exaggerated in size, and the distance between the Marianas and the Carolines is underestimated.

Until the publication in 1972 of David Lewis's now classic *We, the Navigators,* there was little appreciation of the common basis of navigational methods practiced throughout the islands and archipelagoes of Oceania.[37] By combining a thorough search of the literature with extensive voyages to contact and sail with surviving traditional navigators, Lewis was able to show that all the individual traditions shared a common basis and therefore could be thought of as parts of a single Pacific Island navigational system. This system can be outlined in terms of three main tasks that all navigators must carry out: orientation and course setting; dead reckoning and keeping on course; making landfall.[38]

A few words on gender and navigation are in order before we consider how Oceanic navigators accomplished these tasks. Traditional navigation is typically discussed as a preeminently male activity, yet there are a few references here and there to the participation of women in navigation. For example, in their discussion of the master navigators of the Marshall Islands during the first decades of the twentieth century, Krämer and Nevermann noted that some were women, including one woman who also taught navigation.[39] Although they did not elaborate on their remark, perhaps relevant is an observation shared with me by anthropologist Mimi George about navigators in the Santa Cruz Islands of Melanesia. In one family a navigator had trained his daughters to help him at sea, and perhaps also to ensure that the family navigational tradition was transmitted to future generations.[40] It is also interesting that in the Caroline Islands a young woman is mythically credited with passing navigational knowledge derived from a spirit to her two sons, who in turn founded the two "schools" of Carolinian navigation.[41] The masculine pronouns used in this chapter to refer to navigators are thus not intended to deny a possible female role in this art.

ORIENTATION AND COURSE SETTING

Because of the rotation of the earth, stars appear to rise in the east and set in the west, intersecting the horizon at points and following paths across the sky that do not change perceptibly during a navigator's lifetime. Pacific Islanders have long used these regularities to orient themselves and to guide their canoes toward destinations far beyond sight range. Since their methods are still being

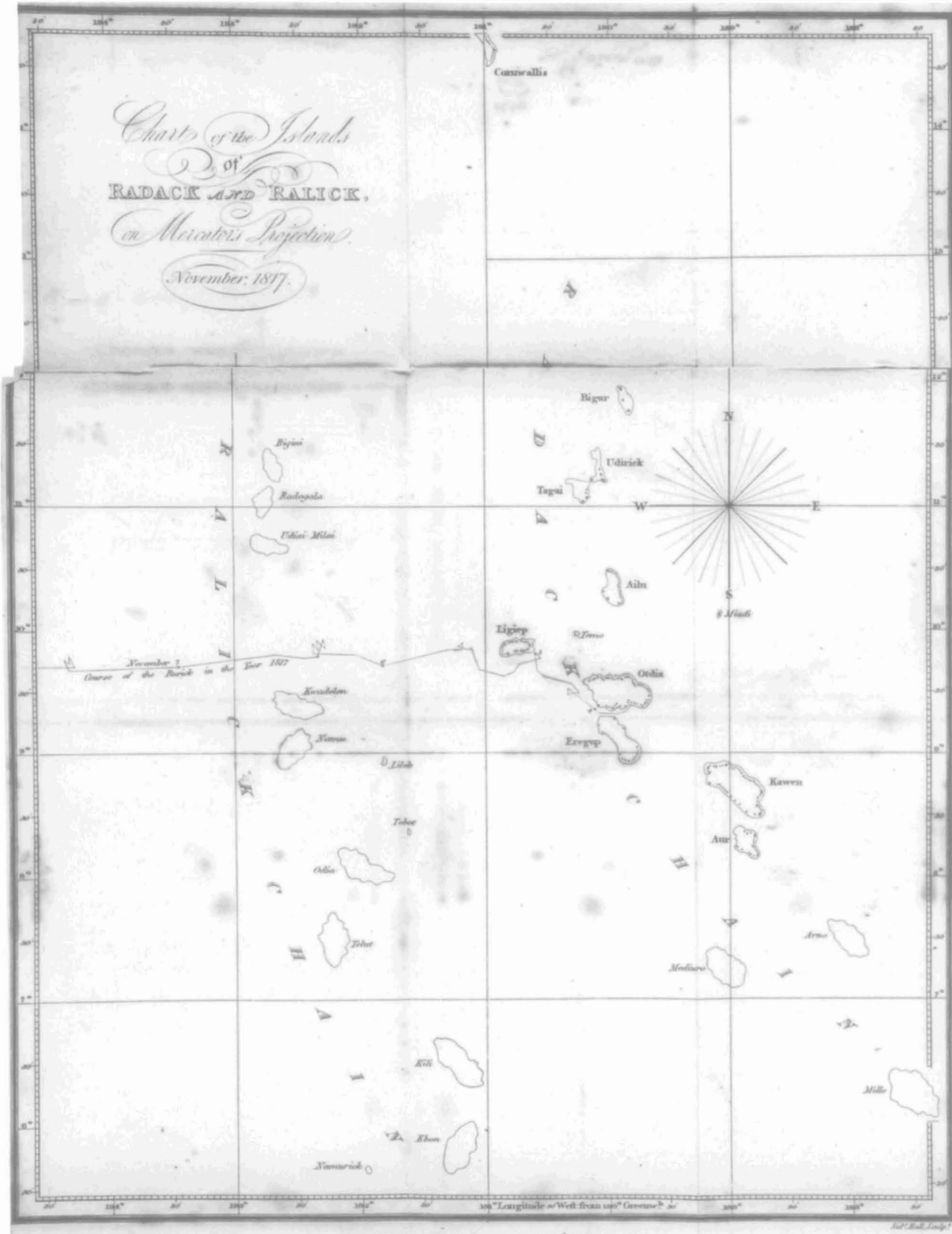
37. David Lewis, *We, the Navigators: The Ancient Art of Landfinding in the Pacific* (Honolulu: University of Hawai'i Press, 1972).

38. This section is adapted from Finney, *Voyage of Rediscovery,* 51–65 (note 5).

39. Augustin Krämer and Hans Nevermann, *Ralik-Ratak (Marshall Inseln)* (Hamburg: Friederichsen, De Gruyter, 1938), 215, 220.

40. Mimi George, personal communication, September 1995.

41. See p. 470 and note 74.



London, Published by Longman & C°. Oct. 8th 1821.

Sid. Hall, Sculp.

employed in some parts of the Pacific, I will describe them here in the present tense.

At night the navigator points the prow of his canoe toward the rising or setting point of the star that has the same bearing as his destination (fig. 13.10). When sailing across wind and current, the navigator picks a star course slightly to one side or the other of the direct course to compensate for the estimated leeway (sideways slipping of a vessel under pressure of the wind) and the direction and strength of the current (fig. 13.11). When the star marking the desired course is too high in the sky to give a good directional reading or is out of sight below the horizon, the navigator keeps himself oriented on other stars that rise and set at the same or nearly the same points on the horizon as the key star and therefore follow the same path across the sky. The navigator must therefore memorize all the prominent stars of such a "star path" to keep oriented and on course throughout the night at all times of the year. In fact, he must know the pattern of the stars throughout the sky so that when clouds obscure the stars being followed, he can look to stars and constellations elsewhere in the sky.

Although it is more convenient to steer a canoe on stars rising or setting in the direction of travel, steersmen are perfectly capable of keeping their canoe on course by facing the stern and keeping it aligned on the stars rising or setting in that direction. Even when clouds blanket all the bow and stern stars, it is still possible to keep a canoe on course by reference to stars off to one side or the other of the course line.[42]

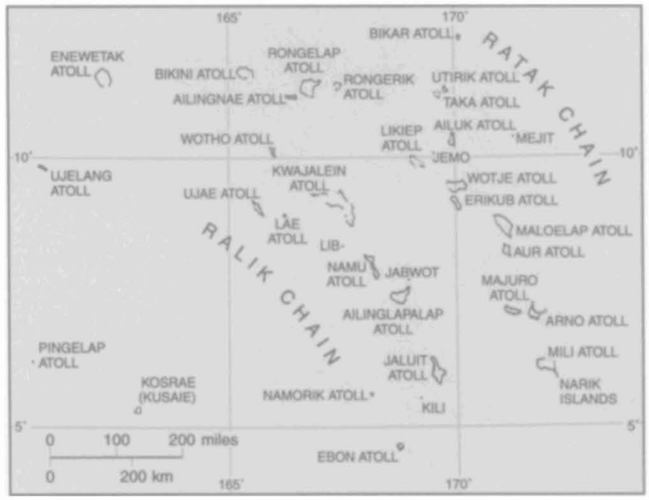


FIG. 13.9. THE MARSHALL ISLANDS. This modern map shows the thirty-four atolls and separate coralline islands of the two chains of Ralik and Ratak. The fit between Kotzebue's chart and this one is best for the Ratak chain, as is to be expected in light of Kotzebue's surveys there and the fact that his navigator-informants were all from that chain. Nonetheless, his lone informant for the Ralik chain seems to have had a fair idea of the location of the central islands of that chain, although he left out the atolls at the extreme northwest end of the chain and his placement of the southern islands is somewhat askew.

During the day, the navigator orients himself on the sun and the pattern of ocean swells. The sun can best be used in the early morning and late afternoon when it is low on the horizon. The navigator must, however, be aware that the rising and setting points of the sun shift daily and must periodically recalibrate the bearing of the sun by watching each morning where it rises with respect to the fading star field of the dawn sky. When the sun rises too

(Facing page)
FIG. 13.8. KOTZEBUE'S CHART OF THE RATAK AND RALIK CHAINS OF THE MARSHALL ISLANDS. In early 1817 the Russian explorer Otto von Kotzebue spent two and a half months in the Marshall Islands of Micronesia. Kotzebue stayed in the central region of the Ratak (eastern) chain, where he questioned Marshallese navigators about the location of the islands they knew. The navigators responded by outlining in the sand all the islands they had sailed to, using coral fragments to stand for individual islets, and indicating by gesture and word the bearing and sailing distances from one island to another. The information given by the navigators, plus Kotzebue's own survey of several islands, resulted in a fairly accurate chart of the Ratak chain. One navigator also provided information on the islands of the Ralik (western) chain that he knew from raids conducted there, which Kotzebue also incorporated in his chart. Although Kotzebue returned to the Ratak chain in November 1817 and sailed from there through the Ralik chain on his way to Kamchatka (see track on the chart), the expedition sighted none of the Ralik islands and so did not have a chance to verify information from the Ratak navigator or to expand on it by interviewing Ralik navigators.
From Otto von Kotzebue, *A Voyage of Discovery into the South Sea and Beering's Straits . . . in the Years 1815–1818*, 3 vols., trans. H. E. Lloyd (London: Longman, Hurst, Rees, Orme, and Brown, 1821), at the back of volume 2. Photograph courtesy of the State Historical Society of Wisconsin, Madison (neg. no. WHi [3X]50544).

42. I was forced to do this one cloudy night in early December 1985 while steering the *Hōkūle'a* toward New Zealand. We had left the Cook Islands and tropical seas behind us and were sailing southwest with a strong breeze from the east. During the short nights of the late austral spring, there were no prominent stars to be seen to the southwest, our direction of travel. Accordingly, we found ourselves steering mostly by facing astern and using the rising Pleiades or Orion's belt (adjusting for differences in declination from the exact star path we were using) to keep the canoe on course.

That particular night, however, thick clouds blocked all the stars astern from view, and most of the rest of the sky was also obscured. Only toward the south could any stars be seen, and my job was to keep the canoe heading southwest by maintaining a fixed angle between the Southern Cross and the longitudinal axis of the canoe and then adjusting this for the constellation's rotation around the celestial south pole. But after about an hour the spreading clouds covered the Cross, leaving only the two bright stars pointing directly toward the Cross for steering. When the clouds began to block these pointers as well, I spotted two fuzzy light spots that are known as the Magellanic Clouds but are actually separate galaxies outside our own.

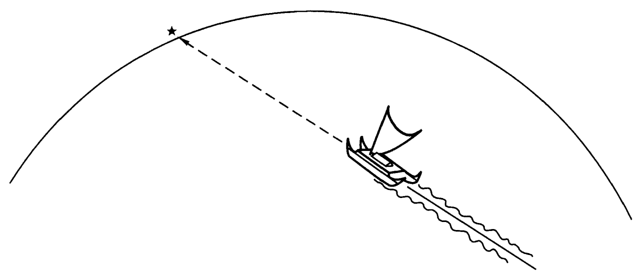


FIG. 13.10. SAILING TOWARD A STAR LOW ON THE HORIZON. This maneuver is basic to oceanic course setting and steering. This diagram ignores current and leeway.
By permission of Ben Finney.

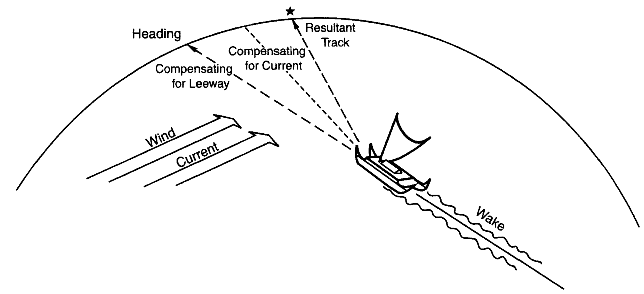


FIG. 13.11. COMPENSATING FOR CURRENT AND LEEWAY WHEN COURSE SETTING AND STEERING BY HORIZON STARS.
By permission of Ben Finney.

high in the sky to serve as a precise directional guide, the navigator can use the pattern of ocean swells to keep the canoe on course–as he must do anytime it is so solidly overcast that he cannot discern the position of the sun. Similarly, when it is too overcast at night to see any stars, any planets, or the moon, the navigator falls back on the ocean swells to keep himself oriented.

The ocean swells most useful to the navigator are not those raised by local winds, but long, regular swells generated by steady winds blowing over long stretches of ocean or by distant storm centers. Amid the often confusing pattern of swells coming from several directions at once, the navigator picks out the most prominent and regular ones and keeps track of their alignment in reference to horizon stars (or the rising or setting sun) so that he can use them for orientation anytime the sky becomes overcast or the sun is too high in the sky to yield an accurate bearing.

The navigators from the Caroline Islands of Micronesia are particularly noted for visualizing a series of bearings along the horizon by the rising and setting points of the key stars and constellations. That writers commonly call this conception a "star compass" is perhaps unfortunate, because it is not a physical instrument like a magnetic compass. It might better be called a "star compass rose" in that it is a directional framework, not an instrument that mechanically indicates direction. Furthermore, it is primarily a mental construct, a conceptual system by which the navigator mentally divides the horizon surrounding him according to celestial referents. Although he may demonstrate this construct to his pupils ashore by placing a circle of pebbles on a mat to mark the rising and setting points of the key stars and constellations, the navigator sets sail with only a conceptual vision engraved in the mind through years of study and practice. This compass and associated navigational and cartographic practices are discussed in detail in the section on Carolinian navigation below.

Although we do not know nearly as much about the now largely forgotten Polynesian navigational methods as we do about the still-practiced Carolinian ones, there can be no question that the Polynesians set their courses by the stars and other celestial bodies, and that they did so skillfully. Both Cook and Banks wrote about Tahitian stellar navigation methods, as did the Spanish navigator José Andía y Varela, who visited Tahiti in 1774, four years after Cook first touched there, and wrote the following succinct entry in his journal about how the Tahitians navigated:

> When the night is a clear one they steer by the stars; and this is the easiest navigation for them because, these being many [in number], not only do they note by them the bearings on which the several islands with which they are in touch lie, but also the harbours in them, so that they make straight for the entrance by following the rhumb of the particular star that rises or sets over it; and they hit it off with as much precision as the most expert navigator of civilised nations could achieve.[43]

These and other accounts make it clear that Polynesian voyagers used star bearings for navigation, but we have no detailed descriptions of any Polynesian star compass similar to that employed by Carolinian navigators. This lack may be because Polynesians did not conceptualize one or simply because no one bothered to record their ideas before they were lost.

Although evidence for Polynesian stellar directional systems may be unclear, information recorded in the nineteenth century from several archipelagoes indicates that the navigators there conceptualized a wind rose in which the horizon was divided into twelve, twenty-four, or thirty-two points named according to the winds that characteristically blow from each point. Figure 13.12 shows a diagram of a thirty-two-point wind rose from the

43. "The Journal of Don José de Andía y Varela," in *The Quest and Occupation of Tahiti by Emissaries of Spain during the Years 1772–1776,* 3 vols., comp. and trans. Bolton Glanvill Corney, Hakluyt Society Publications, ser. 2, nos. 32, 36, 43 (London: Hakluyt Society, 1913–19), 2:221–317, esp. 286; brackets in original.

Cook Islands as drawn by the nineteenth-century missionary William Wyatt Gill, who wrote that the islanders used a large gourd to symbolize the distribution of winds. Small holes were drilled in the lower part of the gourd to correspond to the "wind pits" from which the various winds blow and then plugged with pieces of tapa cloth that supposedly could be manipulated to control the wind.

> Should the wind be unfavourable for a grand expedition, the chief priest began his incantation by withdrawing the plug from the aperture through which the unpropitious wind was supposed to blow. Rebuking this wind, he stopped up the hole, and advanced through all the intermediate apertures, moving plug by plug, until the desired wind-hole was reached. This was left open, as a gentle hint to the children of Raka [the god of winds] that the priest wished the wind to blow steadily from that quarter.

Gill wryly added, however, that because the priest would have had "a good knowledge of the ordinary course of the winds, and the various indications of change, the peril of the experiment was not great."[44]

Polynesian wind roses are reminiscent of the wind rose of eight points formerly used by Mediterranean seafarers, in which each point is named for the prevailing wind. Given the shifting nature of the winds in the Mediterranean, it has been said that early mariners there must have been "able to recognize these winds either by their characteristics of temperature, moisture content, etc., or else by association with sun, moon, or stars, otherwise it would be hardly possible to use a wind-rose for purposes of navigation with any degree of certitude."[45] Similarly, it seems likely that Polynesian navigators used their wind roses primarily for conceptualizing directions but ultimately relied on celestial referents to set their course and steer it.

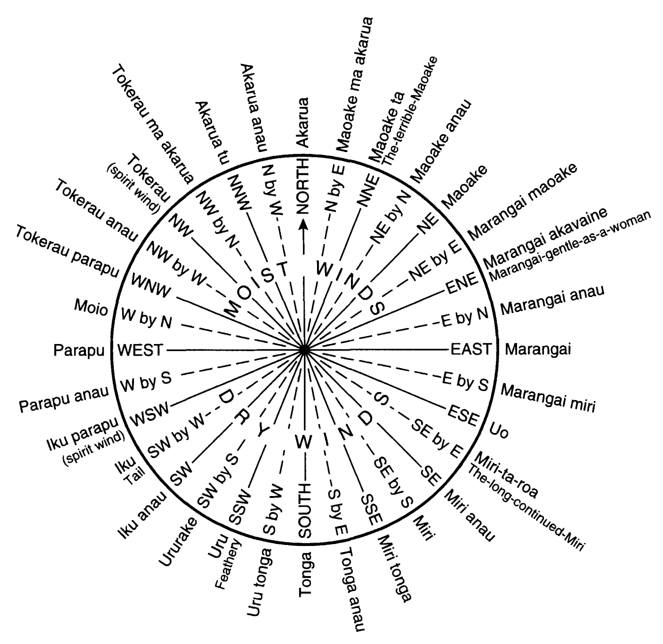


FIG. 13.12. THIRTY-TWO-POINT COOK ISLANDS WIND ROSE. The Cook Islanders of Polynesia conceptualized a wind rose in which each of the thirty-two points represented the direction from which a named wind blew. The missionary William Wyatt Gill, who published this engraving of the wind rose, stated that it was also inscribed around the edge of a large gourd by means of drilled holes. The gourd served as a device for predicting or magically controlling the wind by manipulating tapa cloth plugs for the holes.
After William Wyatt Gill, *Myths and Songs from the South Pacific* (London: King, 1876), 320.

DEAD RECKONING AND KEEPING ON COURSE

As in the Western procedure called "dead reckoning," the island navigator effectively keeps track of his vessel by integrating his estimates of course and distance covered to arrive at a mental picture of where he is at any one time. But he employs a conceptual system utterly different from the Western one based on compass bearings, miles covered, and lines of latitude and longitude.

The Carolinian navigator, for example, conceptualizes his canoe's progress through the water by picturing how a "reference island" lying off to one side of the course moves under successive star points along the horizon. This is an abstract construct for picturing a canoe's progress, not a precise measure, since the reference island is too far off the course line to be seen from the canoe.

In addition, for voyages made to the north or south, the navigator can also judge progress by the changing angular elevation of stars above the horizon, such as Polaris. Hawaiian astronomers named Polaris Hōkū-pa'a, literally the "immovable star," and further recognized that its angular elevation above the horizon decreased as one sailed south and would disappear below the horizon if one sailed far enough south. For example, a Hawaiian text states that "you will lose sight of the Hoku-paa" when you reach the equator and, referring to the portions of the southern sky not visible from Hawai'i, that then "you will discover new constellations and strange stars."[46]

Based on fragmentary accounts, including one by the nineteenth-century Hawaiian writer Kepelino Keauokalani, Lewis has proposed that Polynesian navigators once

44. William Wyatt Gill, *Myths and Songs from the South Pacific* (London: King, 1876), 319–22, quotation on 321.

45. Kemp, *Oxford Companion to Ships and the Sea,* 942 (note 27).

46. Rubellite Kawena Johnson and John Kaipo Mahelona, *Nā Inoa Hōkū: A Catalogue of Hawaiian and Pacific Star Names* (Honolulu: Topgallant, 1975), 73. (This text is given in full below, pp. 486–87.) Sirius, the brightest star in the sky, now passes almost directly over Tahiti (i.e., its declination is virtually the same as Tahiti's latitude).

used this principle of changing stellar elevations on voyages headed north or south in a particularly precise manner by carefully observing stars that passed directly above specific islands.[47] A star's declination is its celestial latitude–its angular distance north or south of the celestial equator. As it progresses from east to west across the sky, a star passes directly above all places on the globe whose terrestrial latitude equals its declination. If, therefore, a navigator knew what star passed directly above his target island, he would be able to judge when he was approaching the latitude of that island by observing when the star whose declination marked the island (had the same declination as the island's latitude) passed almost directly above him as it crossed the meridian.

The star Arcturus (Hōkūle'a in Hawaiian), provides a case in point, for it now passes directly over the sanctuary at Honaunau, a complex of ancient stone structures found on the southwestern coast of the island of Hawai'i, the largest island in the Hawaiian chain. Arcturus's declination and the latitude of Honaunau are the same: 19°27′ north. A navigator sailing north from Tahiti for Hawai'i could take advantage of this in the following way. He would set a course slightly to the east of Hawai'i and then judge his northward progress by watching Arcturus rise higher and higher in the sky until, at its highest point during its passage across the sky, it was directly over the navigator's zenith, that is, the point in the heavens directly above him. If his observation was accurate he would then be at the latitude of the island of Hawai'i, and if his dead reckoning was also correct, he would be off the eastern, windward side of the island. He could then turn his canoe to the west and sail downwind until the island came into sight.[48]

Such zenith observations cannot, however, be used to set and maintain a course because a star at its zenith does not yield a fixed bearing with reference to the globe. For example, Arcturus passes directly above all places on earth located along 19°27′ north and therefore looks the same at the zenith no matter what the longitude of the observer. The Hawai'i-bound navigator sailing north from Tahiti who wished to use Arcturus to judge when he had reached the latitude of Hawai'i would still have to gain his bearings by reference to the rising and setting points of the stars, then use his observational and dead reckoning skills to keep the canoe heading on the proper course to reach Hawai'i–ideally off its eastern, windward flank.

MAKING LANDFALL

To make landfall on small island targets, particularly on low atolls that cannot be seen until they are ten to twelve miles away, navigators expand their ability to detect land beyond direct sight range by sensing when their canoes approach an island. The most widely used method is to watch for those birds–particularly the terns, noddies, and boobies–that sleep each night on land but fly out to sea at dawn to fish. Adults of these species with chicks to feed seldom fly beyond forty miles from their home island in any sizable numbers.

Navigators also look for signs of islands in the clouds: for example, a characteristic piling up of clouds along the horizon indicating that a high island is disrupting the flow of the trade winds and accompanying clouds or a greenish hue on the underside of clouds made by the reflection from the shallow lagoon of an atoll below it, as with the atoll of Ana'a in the Tuamotus. Phosphorescent streaks of light occurring deep below the surface and pointing to or from islands are yet another way of detecting land still below the horizon, although the physical basis is not yet clear. Ocean swells bouncing back from an island ahead, bending around it, or intersecting with one another after being deflected by an island provide clues for another technique that greatly expands the detection range of islands beyond their visual range, one that will be discussed in the section on the Marshall Islands.

The Issue of Navigational Accuracy

Doubts about the accuracy of traditional Oceanic navigation have been expressed intermittently over the past four centuries by ethnocentric writers who have questioned whether it was possible to intentionally navigate to distant islands without the magnetic compass and other aids. The most recent outbreak of such skepticism occurred in the late 1950s and early 1960s when critics charged that the probability for error in reading star compass points, in keeping on course in cloudy weather, and in estimating the current were so great that the image of the Polynesians and other Pacific Islanders as great navigators was nothing but a romantic myth. The Aotearoa

47. Kepelino Keauokalani, *Kepelino's Traditions of Hawaii,* ed. Martha Warren Beckwith, Bishop Museum Bulletin, no. 95 (Honolulu: Bernice P. Bishop Museum Press, 1932), 82–83, and Lewis, *We, the Navigators,* 278–90 (note 4).

48. As star declinations slowly shift with the precession of the equinoxes, a star's path over the earth's surface also slowly shifts. For example, in A.D. 1000 Arcturus had a declination of 24°39′ north and thus passed over the Hawaiian chain north of the island of Kaua'i (Lewis, *We, the Navigators,* 283). Lewis tested the feasibility of this "zenith star" method on his 1964 voyage from Tahiti to New Zealand aboard a modern catamaran. By adjusting the stays of the mast of his catamaran to make it vertical to the surface of the sea, then sighting up the mast, Lewis was able to ascertain what stars were passing directly overhead and thereby keep track of his changing latitude as he sailed southwest for New Zealand. While sailing *Hōkūle'a* to Tahiti in 1976, Lewis and I experimented with this method and found that we could judge our latitude to within half a degree or so (David Lewis, "Stars of the Sea Road," *Journal of the Polynesian Society* 75 [1966]: 85–94, and Ben R. Finney, *Hokule'a: The Way to Tahiti* [New York: Dodd, Mead, 1979], 212–16).

(New Zealand) historian Andrew Sharp went so far as to claim that such errors would necessarily accumulate so fast that it was impossible to traditionally navigate between islands separated by more than three hundred miles of open ocean. The far-flung islands of Oceania could have been settled, he concluded, only by a long series of maritime accidents. He posited that canoes making short crossings wandered (or were blown) off course and were then pushed by wind and current to uninhabited islands, or that canoes carrying refugees who had fled their homes because of war or famine, leaving their fate to the mercy of the winds and currents, fortuitously fetched up on such islands.[49]

Sharp's claim about the impossibility of navigating between islands more than three hundred miles apart has since been amply refuted by the Caroline Islanders who in the 1970s revived the old practice of sailing between the Carolines and Marianas, archipelagoes separated by over four hundred miles of open ocean.[50] Furthermore, since 1976 the *Hōkūle'a* has repeatedly been sailed over the legendary sea routes of Polynesia on voyages between islands separated by many hundreds of miles of blue water, and in some cases more than two thousand miles, without instruments or physical charts.

Two main factors aid such long-distance navigation. First, the inevitable errors in estimating star bearings with the naked eye, in steering on the swells when the sky is totally overcast, in judging the effects of unseen currents, and in estimating distance traveled do not necessarily accumulate in one direction to throw a canoe progressively off course the longer it sails.[51] Second, most of the islands of Oceania occur within archipelagoes, meaning that navigators typically can sail between groups of islands rather than making their way from one lone island to another, lost in the vastness of the sea.

Although the significance of being able to sail between groups of islands rather than between lone, isolated ones cannot be overestimated, the challenge to navigation presented by the few solitary and truly isolated islands found in Remote Oceania should not be underestimated. Rapa Nui (Easter Island), the most remote and solitary island of the Pacific to be permanently settled, provides a prime example. There are no other islands immediately around Rapa Nui, and the nearest permanently inhabited high island is Mangareva, 1,450 miles to the west. (Tiny Pitcairn Island and the even smaller raised coral island of Oeno are several hundred miles closer, but these were only temporarily occupied by Polynesians.) Initially finding this lone island might not have been that difficult for the first Polynesian explorers who ventured beyond the frontiers of settlement along the eastern margins of the Marquesas, Tuamotus, and Australs. Migratory land birds flying to Rapa Nui from the west would have given them a bearing to follow, and the abundance of birds nesting on the island (before humans arrived and, with them, the predatory rat) would have strongly advertised the island's presence to any voyagers who came near. But once the first settlers became established, bird populations were greatly affected by hunting as well as by the rats they introduced. Then clearing land for agriculture and harvesting trees turned the once-forested flanks of the island into desiccated, windswept grasslands. The resulting crash in the populations of birds migrating through and nesting on Rapa Nui, combined with its lack of an archipelagic screen to aid navigation, must have discouraged further visits from the archipelagoes to the west. With no trees left for the islanders themselves to build voyaging canoes, Rapa Nui was cut off from the rest of Polynesia.[52]

Caroline Island Navigation and Cartography

Traditional Oceanic navigation is best documented in Micronesia's Caroline Islands. These extend over thirty-two degrees of longitude but are mostly concentrated in a narrow band between six and ten degrees of latitude north of the equator. We are primarily concerned with the central Carolines, the atolls that lie between the large and mostly high islands of Belau (Palau) and Yap (Uap) in the west and the high island (though surrounded by a huge barrier reef) of Truk (Chuuk) in the east.

Detailed descriptions of Carolinian navigation were not gathered until the late nineteenth century. The lengthy

49. Sharp, *Ancient Voyagers* (note 4), and Andrew Sharp, "Polynesian Navigation to Distant Islands," *Journal of the Polynesian Society* 70 (1961): 219–26.

50. Michael McCoy, "A Renaissance in Carolinian-Marianas Voyaging," in *Pacific Navigation and Voyaging*, comp. Ben R. Finney (Wellington: Polynesian Society, 1976), 129–38, and Finney, "Voyaging Canoes" (note 5).

51. The random effects of errors in dead reckoning during the 1980 voyage of *Hōkūle'a* from Hawai'i to Tahiti were documented (after the crossing had been completed) by comparing where the navigator reckoned the canoe had sailed with precise data on the actual track and on the currents flowing across it, gathered by passing satellites from automatic transmitters installed on the canoe and on buoys dropped parallel to the course line. During that voyage the navigator, who was making his first long crossing employing traditional navigational techniques, failed to perceive that the canoe was pushed ninety miles to the west while crossing one of the swift, narrow current jets that occur close to the equator where the Coriolis effect is relaxed. Then, sailing slowly in light airs south of the equator, he overestimated the strength of the westward-flowing south equatorial current, which, as was later learned, was then very weak. But these two errors, if they may be called such, did not compound. Instead, the second one canceled out the first, and by the time the canoe was approaching Tahiti the navigator's mental picture of where they were sailing turned out to more or less coincide with the actual track of the canoe. Ben R. Finney et al., "Re-learning a Vanishing Art," *Journal of the Polynesian Society* 95 (1986): 41–90.

52. Ben R. Finney, "Voyaging and Isolation in Rapa Nui Prehistory," *Rapa Nui Journal* 7 (1993): 1–6.

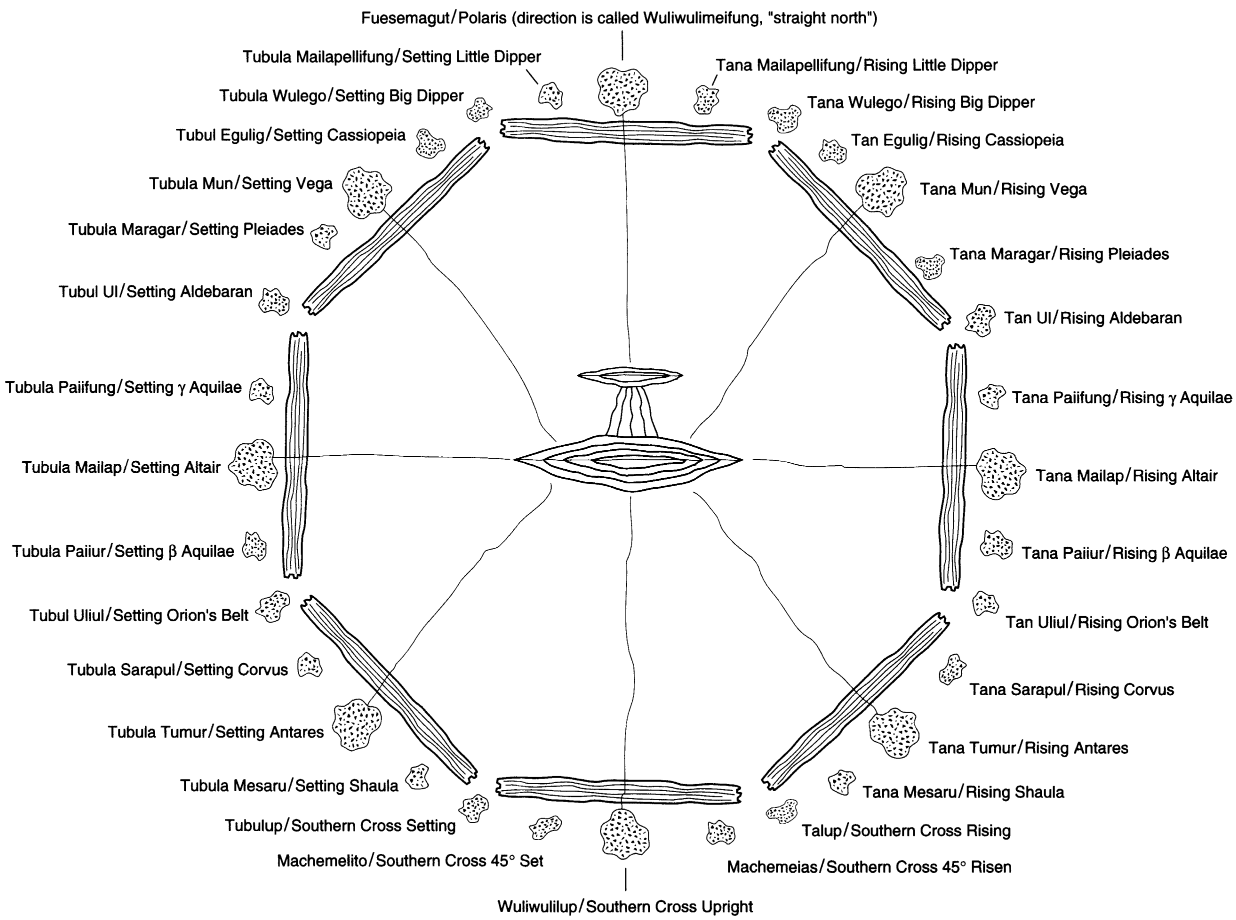


FIG. 13.13. CAROLINIAN STAR COMPASS. Carolinian navigators arrange lumps of coral, coconut leaves, and banana fibers on a mat to teach students the sidereal compass. In this compass from Satawal Atoll lumps of coral are laid out in a circle to represent the thirty-two compass points, but they are spaced unevenly since each one stands for the actual rising or setting point of the particular star or constellation. (Rising points are indicated by the prefix *tan,* setting by the prefix *tubul;* both with an *a* suffixed to bridge consonants.) Banana fibers strung across the principal axes demonstrate reciprocal star courses. A small canoe of coconut leaves in the center helps the student visualize himself at the center of various star paths. Bundles of coconut leaves placed just inside the ring of coral lumps represent the eight swell directions used in steering.
After S. D. Thomas, *The Last Navigator* (New York: Henry Holt, 1987), 81.

but limited Spanish interest in these islands did not result in any sustained inquiries into the navigational skills of their inhabitants. The first such research was conducted by German scholars who worked in the Carolines from the late 1800s, just before Germany purchased colonial rights to them from Spain, until Japan took them over at the start of World War I. Their pioneering inquiries, along with the more intensive work carried out after World War II by American and Japanese researchers, provide a fair idea of how the Carolinians navigate. This knowledge includes how they envision the islands around them and employ their mental constructs to teach novices, how they guide their canoes, and how knowledge is passed on to their pupils.[53] It would be hubris to claim, however, that we fully understand the way Carolinian navigators think and work. As will be ap-

53. German sources include A. Schück, "Die astronomischen, geographischen und nautischen Kentnisse der Bewohner der Karolinen- und Marshallinseln im westlichen Grossen Ozean," *Aus Allen Welttheilen* 13 (1882): 51–57 and 242–43; E. Sarfert, "Zur Kenntnis der Schiffahrtskunde der Karoliner," *Korrespondenz-Blatt der Deutschen Gesellschaft für Anthropologie, Ethnologie und Urgeschichte* 42 (1911): 131–36; and Paul Hambruch, "Die Schiffahrt auf den Karolinen- und Marshallinseln," *Meereskunde* 6 (1912): 1–40. More recent sources include Tomoya Akimichi, "Triggerfish and the Southern Cross: Cultural Associations of Fish with Stars in Micronesian Navigational Knowledge," *Man and Culture in Oceania* 3, special issue (1987): 279–98; idem, "Image and Reality at Sea: Fish and Cognitive Mapping in Carolinean Navigational Knowledge," in *Redefining Nature: Ecology, Culture and Domestication,* ed. Roy Ellen and Katsuyoshi Fukui (Oxford: Berg, 1996), 493–514; William H. Alkire, "Systems of Measurement on Woleai Atoll, Caroline Islands," *Anthropos 65* (1970): 1–73; Gladwin, *East Is a Big Bird* (note 1); Goodenough, *Native Astronomy* (note 4); Lewis, *We, the Navigators* (note 4); and S. D. Thomas, *The Last Navigator* (New York: Henry Holt, 1987). Frédéric Lutké, *Voyage autour du monde* (Paris, 1835), 2:68–69, reports that the Caroline Islanders tattoo their bodies with long straight lines and images of small fish associated with the names of islands.

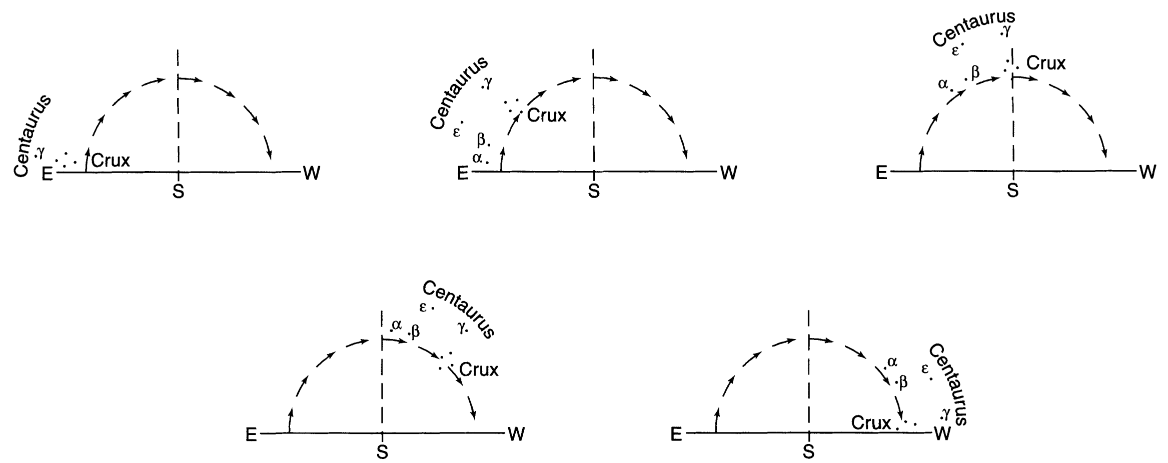


FIG. 13.14. SOUTHERN CROSS STAR POSITIONS AS SEEN LOOKING SOUTH FROM THE CAROLINE ISLANDS. Carolinians employ these five positions (rising on horizon, rising at forty-five degrees, upright, setting at forty-five degrees, setting on horizon) for five points of their thirty-two-point star compass.

After Ward Hunt Goodenough, *Native Astronomy in the Central Carolines* (Philadelphia: University Museum, University of Pennsylvania, 1953), 17.

parent in the summary that follows, there are differences in the way various researchers have presented the material, and some major points require further research.

Carolinian navigators employ a conceptual construct that in the language of Satawal Atoll is called a *nááng*, literally, "heaven" or "sky."[54] This is generally known in English as a "star compass," "sidereal compass," or "star path compass." Although they do not take any physical representations of this compass to sea with them, they do outline it on the ground to teach aspiring navigators basic principles. Figure 13.13 reproduces a sketch, made in the early 1980s by yachtsman Stephen D. Thomas, of such a teaching device as it was demonstrated to him on Satawal Atoll when he was doing research on navigation there.[55] Thirty-two lumps of coral are shown arrayed at more or less equal intervals in a rough circle to stand for the compass points named for the azimuths, or bearings, of the rising and setting points of such prominent stars as Vega and Antares and such constellations as the Pleiades and Corvus, as well as in the north the azimuth of Polaris and in the south that of the five positions of the Southern Cross (Crux) as it rotates around the celestial south pole (fig. 13.14).[56] Banana fibers extending from the perimeter to the center of the circle indicate the principal axes of the compass, and coconut fronds placed along the inner edge of the circle indicate the main swell directions. A model canoe made from coconut leaves is placed at the center and manipulated by the instructor to help his pupils visualize sailing to or from various compass points and anticipate how their vessel will be pitched or rolled by the main swells.

According to Thomas's diagram, as well as those published by anthropologist Tomoya Akimichi, who has also recently worked on Satawal, the navigators there typically arrange the coral lumps of their star compass in a circle.[57] However, the first German reports of Carolinian compass representations indicated that the navigators arranged the rocks on a quadrangular plan rather than a circular one.[58] Navigators from Woleai Atoll interviewed by anthropologist William Alkire in the 1960s stressed that they always outlined the star compass in this quadrangular way (fig. 13.15) and also explained to him that this format did not affect the function of the compass. In fact, they claimed that having four corners made it easier to memorize the order of the star and constellation points arrayed along the perimeter of the compass.[59] Although the preference for the circular or the quadrangular form may reflect regional differences, most scholars assume that the quadrangular form was original and that the influence of the magnetic compass, with its thirty-two points marked out on a circular compass card, has led contemporary navigators to portray the thirty-two points of their star compass as a circle. Note, however, that although two of the navigators Alkire interviewed were thoroughly familiar with the magnetic compass from their service on trading ships, they still conceived of the star compass as a traditional quadrangle.

Today virtually all Carolinian navigators employ a magnetic compass during the day to avoid the difficult

54. Akimichi, "Image and Reality," 495.
55. Thomas, *Last Navigator,* 81 (note 53).
56. Goodenough, *Native Astronomy,* 15–17 (note 4).
57. Akimichi, "Image and Reality," 497, and idem, "Triggerfish," 282 (both in note 53).
58. Sarfert, "Zur Kenntnis der Schiffahrtskunde" (note 53).
59. Alkire, "Systems of Measurement," 41–43 (note 53).

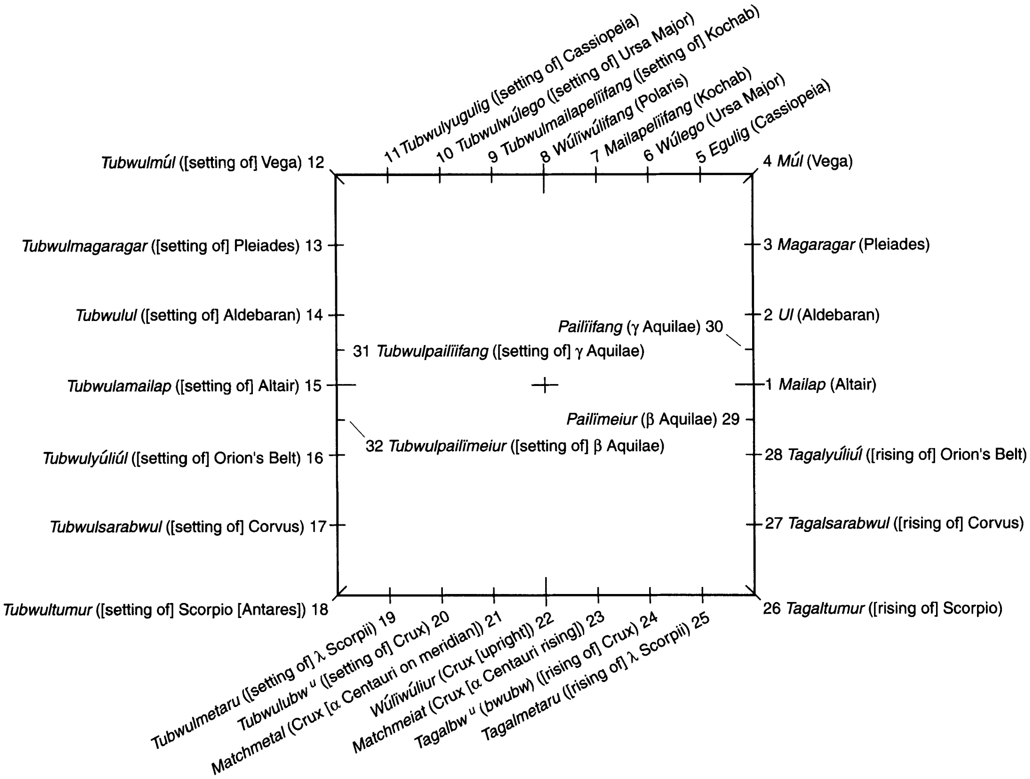


FIG. 13.15. "STAR PATH" COMPASS FROM WOLEAI ATOLL, CAROLINE ISLANDS. Each star path, or compass point, is known by its key star or constellation.

After William H. Alkire, "Systems of Measurement on Woleai Atoll, Caroline Islands," *Anthropos* 65 (1970): 1–73; esp. 42–43.

task of steering by the sun during the early morning and late afternoon and by the swells in the middle of the day. At night, however, they typically prefer to steer by the stars because–as most modern sailors will agree–it is easier to follow a steady star than the ever-swinging needle of a compass. Furthermore, even when using a magnetic compass, they still verbalize its bearings in terms of traditional celestial referents rather than using directional terms such as north or north by west.

As portrayed by Thomas and Akimichi, the points of the Satawal compass are evenly spaced around its perimeter. Even though the compass points on Alkire's outline of the Woleai compass are unequally spaced along its four sides, the angles between them are equal except for the rising and setting points of β and γ Aquilae. According to Alkire, these points (nos. 29–32 in fig. 13.15), which closely flank the rising and setting points of Altair (nos. 1 and 15 in fig. 13.15), are auxiliary to the other twenty-eight points of the compass.[60] In contrast to the even spacing of points on the Satawal compass and, with the exception above, the Woleai compass as well, the points are irregularly spaced in the way the Carolinian compass is most frequently represented in the literature. These representations stem from Goodenough's portrayal of the compass in his 1953 monograph on Carolinian astronomy (fig. 13.16) in which, drawing from early German reports, he plotted the compass points according to the actual rising and setting points of the named stars and constellations.[61] His diagram looks even more irregular because the east-west axis is drawn north of the celestial equator, reflecting the star path of Altair, the star of primary orientation that passes directly over the long axis of the Caroline chain.

This discrepancy could be explained by assuming that originally the star compass points were spaced irregularly according to star azimuths, and that the equal spacing of compass points came with the introduction of the magnetic compass. As suggested by Charles O. Frake, however, it seems more likely that these two presentations of the compass simply reflect the differing approaches of the researchers. Whereas Thomas, Akimichi, and Alkire were ethnographically reporting how the Carolinians conceive of the star compass in their minds and ephemerally represent it on the ground, in his study of Carolinian astronomy Goodenough chose to represent it analytically in terms of the actual azimuths of its defining stars and constellations. Accordingly, Frake's solution to the confusion

60. Alkire, "Systems of Measurement," 44.

61. Goodenough, *Native Astronomy*, 5–6 (note 4).

seems sensible: "The stars provide the names, not the positions, for abstract conceptual segmentations of the horizon circle into 32 equally spaced points."[62]

Of course the Carolinian navigators do not just name their compass points after stellar bodies. They also use the stars and constellations to set courses and to steer their canoes. Although such dual use might seem confusing, it does not trouble them. Just as they are able to adjust the heading of their vessels to the right and left of the bearing of the island they are heading toward to compensate for the effects of current and leeway, these consummate navigators can adjust for the differences between the actual rising and setting azimuths of their navigational stars and the evenly spaced compass points named after them.

That Carolinians divide the horizon into thirty-two points just as is done on the card of the modern magnetic compass does not necessarily mean the two constructs are historically connected. Both compasses (as well as the wind rose from Polynesia's Cook Islands) were probably constructed by halving the horizon and resultant sections until it had been divided into thirty-two divisions. These turn out to be 11.25 degrees wide, about as fine as possible for practical use by a steersman and also approximately equivalent to the width of one's fist held at arm's length.[63] But whereas the points of the Western compass were named, initially at least, for wind directions, as seems to have been true in Polynesia as well, the Carolinians looked to the starry heavens to label their compass points.

In his article on measurement systems on Woleai Atoll, which includes the rectangular representation of the compass, Alkire describes how novice navigators learn the compass and then learn the various compass courses to and from the islands in their sailing range though a series of formal steps.[64] The first step focuses on the mnemonic recitation of "star paths" (*pafü*), which Alkire likens to the Western exercise of "boxing the compass" (reciting the points in the correct order). The master navigator instructs his student by representing the points of the star compass (which Alkire prefers to call the "star path compass") with small coral pieces placed on the ground or on a mat in the rectangular form outlined in figure 13.15. The novice then memorizes and recites the compass points in terms of four groups of eight star names. Starting with Altair (1), which Alkire calls the "star of primary orientation" for the compass, the novice moves counterclockwise to Aldebaran (2), Pleiades (3), Vega (4), Cassiopeia (5), Ursa Major (6), Kochab (7), and Polaris (8). Then, starting with Polaris he continues with Kochab setting (9) and on through to Altair setting (15), again eight stars. Following the same process of starting the next set with the last star of the preceding set, the novice continues counterclockwise around the compass for two more sets of eight stars until Altair (1) is reached again. Because of the way the sets overlap, however, only twenty-eight star positions have so far been covered. To complete the series, the novice must then add in the four star positions that closely flank Altair rising and setting: β Aquilae rising (29) and setting (32); and γ Aquilae rising (30) and setting (31).

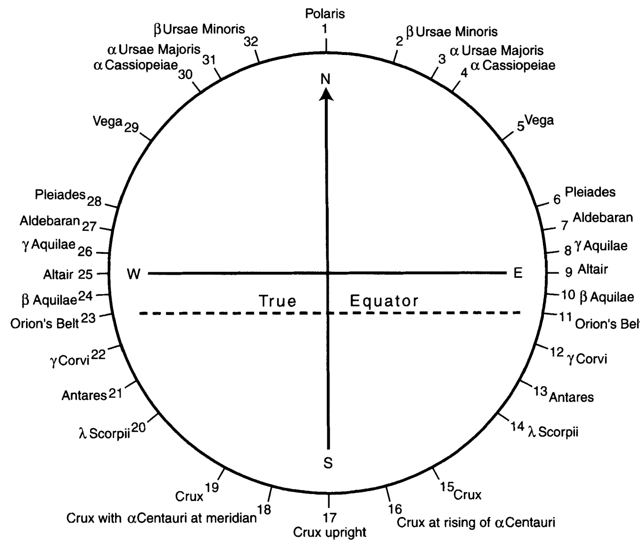


FIG. 13.16. CAROLINIAN STAR COMPASS SHOWN WITH UNEQUALLY SPACED POINTS. The points are placed according to the actual azimuths of the key stars and constellations by which the points are known.
After Ward Hunt Goodenough, *Native Astronomy in the Central Carolines* (Philadelphia: University Museum, University of Pennsylvania, 1953), 6.

The second step involves learning and then reciting two sets of eight pairs of rising and setting stars. The novice begins with Altair rising (1)/Altair setting (15), Aldebaran rising (2)/Aldebaran setting (14), and so on until Polaris (8)/Southern Cross upright (22) is reached. Then he begins again with Altair rising (1)/Altair setting (5) and works south through Orion's Belt rising (28)/Orion's Belt setting (16), and so on, until the set is completed.

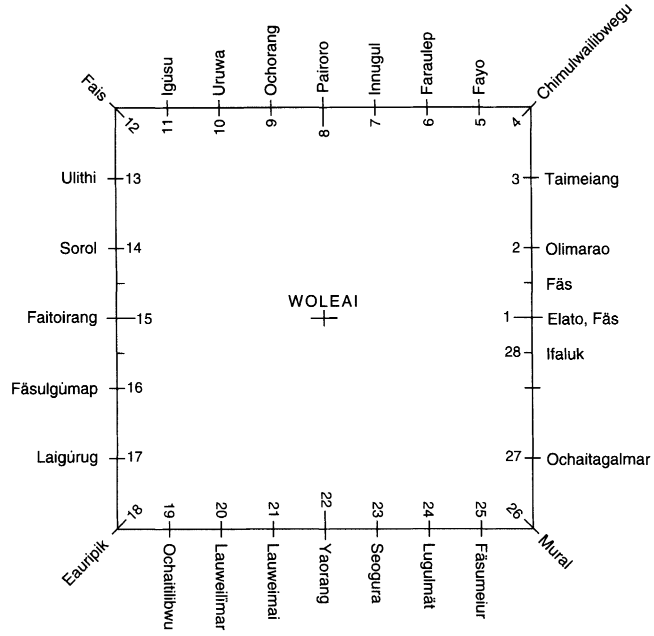
The third step is to learn and recite reciprocal star courses that will enable the navigator to recall immediately the return course for any course he has taken. He begins with Altair rising (1)/Altair setting (15) and proceeds through Aldebaran rising (2)/Orion's Belt setting (14), Pleiades rising (3)/Corvus setting (17), and so on, until all positions are completed.

The fourth step requires the most detailed memorization, for it involves locating all the islands, reefs, and

62. Charles O. Frake, "A Reinterpretation of the Micronesian 'Star Compass,'" *Journal of the Polynesian Society* 104 (1995): 147–58, esp. 155.

63. Frake, "Reinterpretation," 156.

64. Alkire, "Systems of Measurement," 41–47 (note 53).



1. *Fäsalīifaluk*, i.e., "reef of Ifaluk." Fäs is north of Ifaluk (Gamen Reef).
2. Olimarao Island.
3. Special *wofälu* name for a type of small porpoise found along this course line.
4. Woleaian name for Tarang Bank.
5. Gaferut Island.
6. Faraulep Island.
7. *Wofälu* designation for a type of mutton fish said to be some 1.5 feet long.
8. Special name for an unidentified species of bird.
9. A "yellow" reef.
10. Navigational term of reference for a large tropical bird with red feet.
11. Term identifying a barracuda that is seen swimming close to the surface of the water.
12. Fais Island.
13. Ulithi Island.
14. Sorol Island.
15. A reef that lies far below the surface but that is recognized by the large number of birds that feed above it.
16. The reef of "*gùmap*."
17. A whale seen along this course line.
18. Eauripik Island.
19. The reef of the *tilibwu*, which is a small sardinelike fish.
20. An area of many sharks.
21. Also an area of sharks but of a variety somewhat smaller than those of number 20.
22. Refers to a tropical bird with yellow feet.
23. One egret, a type of bird frequenting this area.
24. Identifies a slow-swimming shark that is said to have only half of a dorsal fin.
25. Means reef to the south. It lies close to the surface of the ocean.
26. A local name for Ulloa Reef.
27. A reef named after the man Tagalmar, who is said to have discovered it (probably Ianthe Shoal).
28. Ifaluk Island. This southern course to Ifaluk is used under particular wind conditions.

FIG. 13.17. STAR COURSES (*WOFÄLU*) FROM WOLEAI ATOLL. Carolinian navigators similarly diagrammed for their students the star courses (*wofälu*) radiating outward from each island within their sailing range. This diagram represents such a teaching device for Woleai Atoll, with the courses to islands, reefs and shoals, and places noted for particular kinds of sea life projected onto a rectangular representation of the Carolinian star compass.
After William H. Alkire, "Systems of Measurement on Woleai Atoll, Caroline Islands," *Anthropos* 65 (1970): 1–73, esp. 45–46.

shoals as well as living "seamarks" that are to be found around a particular island starting point. Each island in the Caroline chain therefore has its own conceptual chart indicating the star courses (*wofälu*) to the surrounding islands and other features. But these "charts," whether outlined on the ground or envisioned in the mind, are really just representations of the star compass. It is up to the navigator and his pupils to breathe life into these outlines by mentally or verbally reciting–for each island point of reference–all the islands and other features to be found by sailing along each star course defined by the compass. Figure 13.17 reproduces Alkire's diagram of the rectangular chart centered on Woleai, on which the navigators and then their students point out the islands and other features that lie along each compass bearing.

The living seamarks are forms of birds or sea life, such as a particular whale, a lazily swimming tan shark, a single noisy bird, each said to be associated with a particular place along a star course from a specific island. According to Goodenough and Thomas, "One does not sail to find them, rather one encounters them only when lost and not always then. They serve as a last recourse for the navigator who has missed his landfall or lost his bearings, enabling him to 'align' himself once more in the island world."[65] However, Riesenberg and other writers have stressed the mnemonic utility of these seamarks in filling out the otherwise blank star bearings that do not lead to other islands or physical features.[66]

In addition to memorizing the chart for his own island, the Woleai navigator must know the separate charts for all the islands surrounding Woleai so that once he sails to one of these islands he can visualize from there the bearings to all its surrounding islands and other features and therefore be able to plot his course back to Woleai. Alkire gives the following example: "If the navigator sets sail for Faraulep . . . he bases his course on Ursa major with possible alterations depending on wind and sea conditions at the time of the voyage. On his return voyage from Faraulep he must conceptualize the Island Chart for this island in order to take advantage of all significant reference points he may encounter during his return voyage. These might become crucially important if he should happen to be blown off course during the voyage." Alkire added that two of his navigator informants who shared the same teacher collectively knew from memory the charts centered on eighteen islands extending across the Carolines, meaning that for each successive one they could recite the star course bearings to surrounding islands and other features, thus effectively organizing hundreds of bits of navigational information in a form they could remember and employ at sea.[67]

After learning all the individual island charts, the

65. Ward Hunt Goodenough and S. D. Thomas, "Traditional Navigation in the Western Pacific," *Expedition* 29, no. 3 (1987): 3–14, esp. 7–8.

66. Saul H. Riesenberg, "The Organisation of Navigational Knowledge on Puluwat," in *Pacific Navigation and Voyaging*, comp. Ben R. Finney (Wellington: Polynesian Society, 1976), 91–128.

67. Alkire, "Systems of Measurement," 46 (note 53).

novice memorizes the seasonal order of the rising and setting of a long list of stars, knowledge vital for orientation when the stars defining compass bearings are not visible. After that, he takes lessons on the main swells used for orientation when the stars are not visible. Then instruction moves on to learning what Alkire calls "pole charts." These are lists of islands, reefs, living seamarks, and other navigational features that lie in a straight line along the bearing of a star compass point. The sequence of islands and features lying along a particular bearing is outlined by coral lumps arranged in long lines or "poles" to simplify its memorization.[68]

Another important way for navigationally ordering islands is called *pwuupwunapanap,* or "great triggerfish."[69] The root of this term, *pwuupw,* is polysemic with two main meanings, triggerfish (*Rhinecanthus aculeatus*) and the constellation Southern Cross (Crux), which are cognitively linked by their common diamond shape (fig. 13.18). The four stars of the Southern Cross correspond, respectively, to the mouth (head) of the fish and its dorsal (back), ventral (abdominal), and caudal (tail) fins. With this triggerfish metaphor, navigators can schematically map the relation between islands in terms of one or a series of diamond-shaped mental diagrams of islands and reefs, seamarks, distinctive swells, and where nothing else is available, even imaginary islands.

In these diagrams, the mouth of the fish always faces east and the tail west. The dorsal and ventral fins can serve as either the northern or southern points, depending on which way the fish is flipped. The backbone of the fish serves as a fifth feature of reference. Virtually any suitable arrangement of islands, real and imaginary, reefs, shoals, or living seamarks can be cognitively organized in terms of a single triggerfish or a linked series of them. Figure 13.19 represents two linked triggerfish.

The linkage of the triggerfish metaphor of the second referent of *pwuupw* as Crux becomes apparent when visualizing the islands lying to the south of Saipan in terms of the compass positions defined by the rotation of this constellation. *Pwuupw* as the Southern Cross rises almost directly above Magur at the head of the fish and sets close to the bearing of Fais at the tail. The southbound navigator therefore knows that if he heads his canoe between the rising and setting points of the Cross he will end up in the center of the Carolines, where he will sight islands, reefs, or other familiar features that will enable him to check his position and change his course if necessary (fig. 13.20).

To include more navigational information, navigators can also overlap a number of their diamond-shaped diagrams, using the backbone of one fish to serve as the dorsal or ventral fin of the next, and so on. Figure 13.21 shows such a linked series of overlapping triggerfish diagrams in which the last three diagrams have been offset to take into account that although Guam, Gaferut, and Olimarao are roughly aligned north and south, the islands below Olimarao are skewed to the east. Note that several names represent swells, living seamarks, or mythical or unknown islands and reefs. These conceptual features are evidently needed to fill out the diagram where no islands and reefs are found.

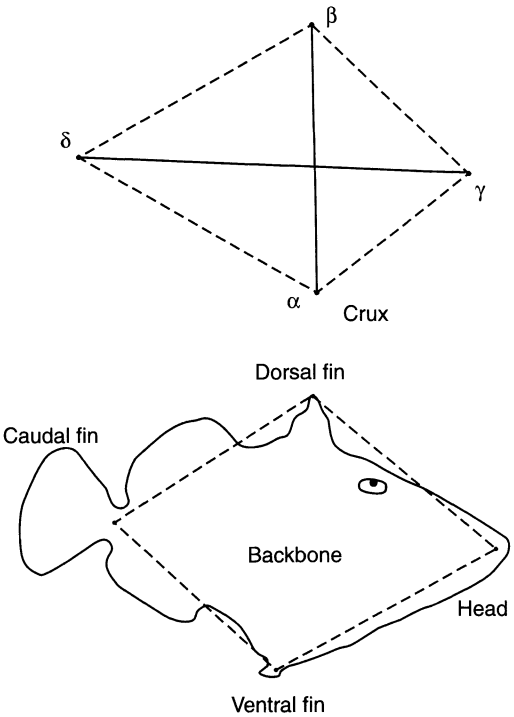


FIG. 13.18. SOUTHERN CROSS AND TRIGGERFISH. Carolinians consider these to have a common shape and call them by the same name. Their shape provides a schematic metaphor called the "great triggerfish" for organizing islands and other information needed by navigators.
After Tomoya Akimichi, "Triggerfish and the Southern Cross: Cultural Associations of Fish with Stars in Micronesian Navigational Knowledge," *Man and Culture in Oceania* 3, special issue (1987): 279–98, esp. 282 (fig. 2).

Although these mental diagrams are not meant to provide exact bearings, they nonetheless can be lifesaving aids when a navigator becomes lost or disoriented. Once he locates one known point in the diagram, from memory he can visualize the rest of the diagram or linked diagrams to get an idea of his position. Then, working directly or indirectly from the bearings chart for the nearest island, he can recalculate his course and get under way.

Various other mnemonic exercises–recitations, songs,

68. Alkire, "Systems of Measurement," 49–50 (note 53).

69. This is in the language of Satawal; in the closely related languages of Woleai and other central Carolinian atolls, cognate terms are used. Since Alkire only briefly describes the great triggerfish ("Systems of Measurement," 51), this summary depends on the studies from Satawal made by Akimichi ("Triggerfish" [note 53]) and Goodenough and Thomas ("Traditional Navigation," 8–10 [note 65]).

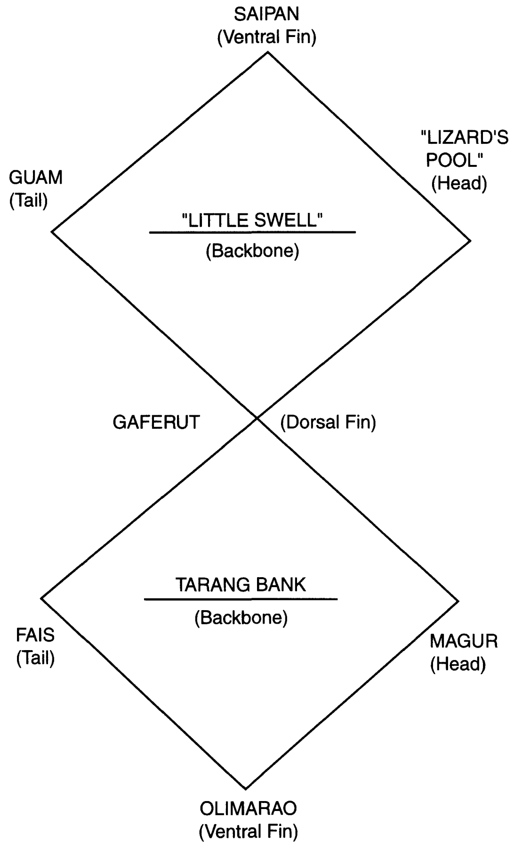


FIG. 13.19. TWO LINKED TRIGGERFISH. This shows the two linked triggerfish by which Carolinian navigators mentally diagram the distribution of islands for sailing from Saipan in the Mariana Islands to Olimarao in the Caroline Islands. The navigator sailing from Saipan conceptually starts at the top of the upper diamond, which in this case is represented by the ventral fin of the fish. Sailing south between the island of Guam to the west at the tail of the fish and "lizard's pool" (a mythical place used to fill in where no islands or reefs exist) to the east at the mouth of the fish, he passes over the backbone noted for its characteristic "little swell" and then proceeds to the island of Gaferut at the dorsal fin. By mentally flipping the fish around its east-west axis, its dorsal fin remains at Gaferut in the lower diamond. The navigator continues southward, passing between the head and tail of the fish, which represent the islands of Magur and Fais, respectively, over the backbone marking the Tarang Bank, and then on to Olimarao Island, the ventral fin, to complete the voyage.
After Ward Hunt Goodenough and S. D. Thomas, "Traditional Navigation in the Western Pacific," *Expedition* 29, no. 3 (1987): 3–14, esp. fig. 9.

chants, oral drills, and even dances–help students memorize all this information and also refresh the memories of practiced navigators by giving form to what would otherwise be stale lists of islands and star courses. For example, a verbal exercise from Puluwat Atoll called "Reef Hole Probing" focuses on the image of a parrot fish that lives in a deep hole in the reef of Puluwat. The participant recites how he is poking a stick into the hole, causing the fish to flee to a reef hole of another island. Then, mentally transferring himself to that island, he again threatens the fish, forcing it to swim to the reef hole of yet another island, and so on, until all the islands of a circular chain around Puluwat are visited and the fish returns to the home island, where it is finally caught. In the recital, each time it flees, the star bearing of its flight to the next island must be given. But to confound the uninitiated, instead of reciting the common names of the islands involved, the navigator calls each one by the secret name of its reef hole.[70]

In another Puluwat exercise, "The Torch of the Lagoon at Anúúfa," the navigator imagines that he carries a torch and seeks fish of various kinds from a series of twenty-two islands. First he recites how to get in position for the exercise by going from Puluwat to the atoll of Magur, where the exercise was invented, and from there to the lagoon of Anúúfa (a spirit) at the mythical island of Fanuankuwel. Then he starts the exercise by verbally carrying the torch in successive voyages to twenty-two places, taking a different star course from Anúúfa to each one. On each trip he captures his prey by the light of his torch and then returns to the lagoon on the reciprocal star course.[71]

The importance of being able to picture navigational information with the mind's eye was stressed by Mau Piailug, the master navigator from the Carolines' Satawal Atoll who guided the reconstructed Polynesian voyaging canoe, *Hōkūle'a,* on her first voyage from Hawai'i to Tahiti in 1976. One evening three years later, as he was coaching the young Hawaiian Nainoa Thompson in how to navigate the canoe to Tahiti, Mau startled Nainoa by asking him, "Can you see Tahiti?" The puzzled Hawaiian wondered what in the world Mau was driving at. From their vantage point on the south shore of O'ahu Island in the Hawaiian chain, Nainoa could point out the star compass bearing to Tahiti, but he knew that since the island lies over 2,250 miles south-southeast of Hawai'i, there was no way he could actually see it. Then Nainoa remembered Mau's urging him to learn to visualize the island he was sailing toward, and he replied that indeed he could "see" Tahiti in that sense. Never lose sight of Tahiti as you sail, the master navigator then told him, for if you do you will be lost. In his aptly titled book *An Ocean in Mind,* Will Kyselka describes how Nainoa went on to apply this and other principles of mental cartography and navigation in taking *Hōkūle'a* from Hawai'i to Tahiti and back in 1980, becoming the first Polynesian navigator in centuries to guide a canoe over this long route.[72]

The traditional Carolinian navigator visualizes the progress of his vessel through the sea in an entirely dif-

70. Riesenberg, "Navigational Knowledge," 94–95 (note 66).
71. Riesenberg, "Navigational Knowledge," 107–10.
72. Kyselka, *Ocean in Mind* (note 5).

ferent way than does his modern counterpart. The latter spreads out a nautical chart showing the location of islands, reefs, and continental shores systematically transformed by Mercator's projection and crisscrossed with lines of latitude and longitude. A compass rose printed on the chart lets him use his parallel rulers to find the compass bearings between points and provide, after compensating for magnetic variation, a heading for the steersmen to follow using a magnetic compass. After setting sail, the modern navigator dead reckons by periodically estimating the course and distance made good from compass readings and measurements of distance run, adjusted for estimated current and leeway and expressed in degrees, nautical miles, and periods of time, then plots this information on his chart. In these days of GPS (global positioning systems), satellite fixes, and computerized steering, dead reckoning may be employed only by particularly conscientious navigators, but it has long been a feature of Western navigation. Before the introduction of the chronometer allowed longitude to be determined precisely, dead reckoning was the primary Western means of tracking position.

The Carolinian navigator has none of his modern counterpart's paraphernalia, yet he manages to keep track of his canoe's progress and to make any course corrections necessary to reach his island destination. On setting sail, he points his canoe toward the memorized star bearing of his target island, adjusting the heading to take into account estimated current and leeway. (Just after sailing he can get an initial idea of these by backsighting on the departure island to compare the actual course made good to the canoe's heading.) As he sails along, the navigator thinks of his progress in a way totally unlike our notion of what happens on a voyage. To him the canoe is stationary and it is the islands that move. Of course he knows that he is sailing the canoe to an island destination and that the latter is not really moving toward him. But just as modern navigators talk about the rising and setting of stars when they know it is the earth that turns, so do Carolinian navigators find it natural to think of their canoes as stationary in relation to moving islands. Their view may be more comprehensible after reading this passage from Gladwin's monograph on Puluwat navigation:

> Picture yourself on a Puluwat canoe at night. The weather is clear, the stars are out, but no land is in sight. The canoe is a familiar little world. Men sit about, talk, perhaps move around a little within their microcosm. On either side of the canoe water streams past, a line of turbulence and bubbles merging into a wake and disappearing in the darkness. Overhead there are stars, immovable, immutable. They swing in their paths across and out of the sky but invariably come up again in the same places. You may travel for days on the canoe but the stars will not go away or change their positions aside from their nightly trajectories from horizon to horizon. Hours go by, miles of water have flowed past. Yet the canoe is still underneath and the stars are still above. Back along the wake, however, the island you left falls farther and farther behind, while the one toward which you are heading is hopefully drawing closer. You can see neither of them, but you know this is happening. You know too that there are islands on either side of you, some near, some far, some ahead, some behind. The ones that are ahead will in due course fall behind. Everything passes by the little canoe–everything except the stars by night and the sun in the day.[73]

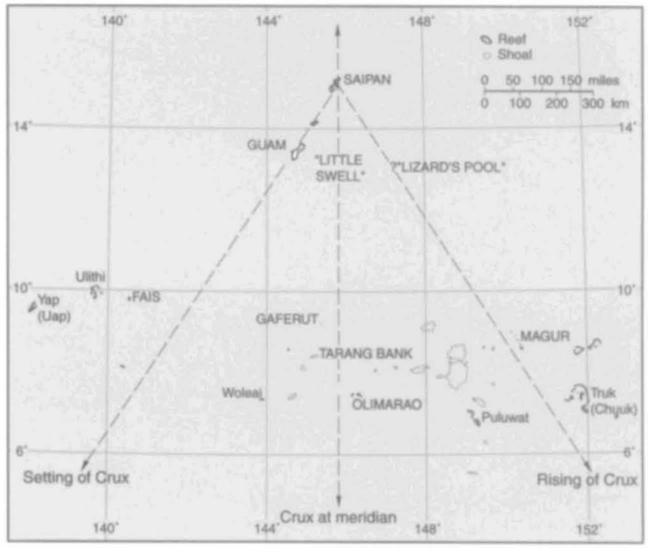


FIG. 13.20. THE "GREAT TRIGGERFISH." This diagram illustrates how the Southern Cross/triggerfish metaphor can incorporate information on star bearings as well as the placement of islands. A navigator looking south from Saipan in the Mariana Islands knows that the atoll of Magur in the Caroline Islands (the head of the triggerfish) bears in the direction of the compass point marked by the rising Southern Cross, and that the atoll of Fais (the tail of the triggerfish) bears almost in the direction of the compass point marked by the setting Southern Cross. By keeping the canoe headed south, toward the upright Southern Cross, he knows that he will end up in the middle of the Caroline archipelago.
After Ward Hunt Goodenough and S. D. Thomas, "Traditional Navigation in the Western Pacific," *Expedition* 29, no. 3 (1987): 3–14, esp. fig. 11.

This canoe-centered perspective parallels the common practice of Western sailors of saying that a channel marker is "drawing abeam," or that an island is "falling astern," when it is obvious that it is the vessel that is moving, not the channel marker or island. The Western sailor typically applies this vessel-centered perspective only to objects he is looking at, however. When he considers ob-

73. Gladwin, *East Is a Big Bird*, 182 (note 1).

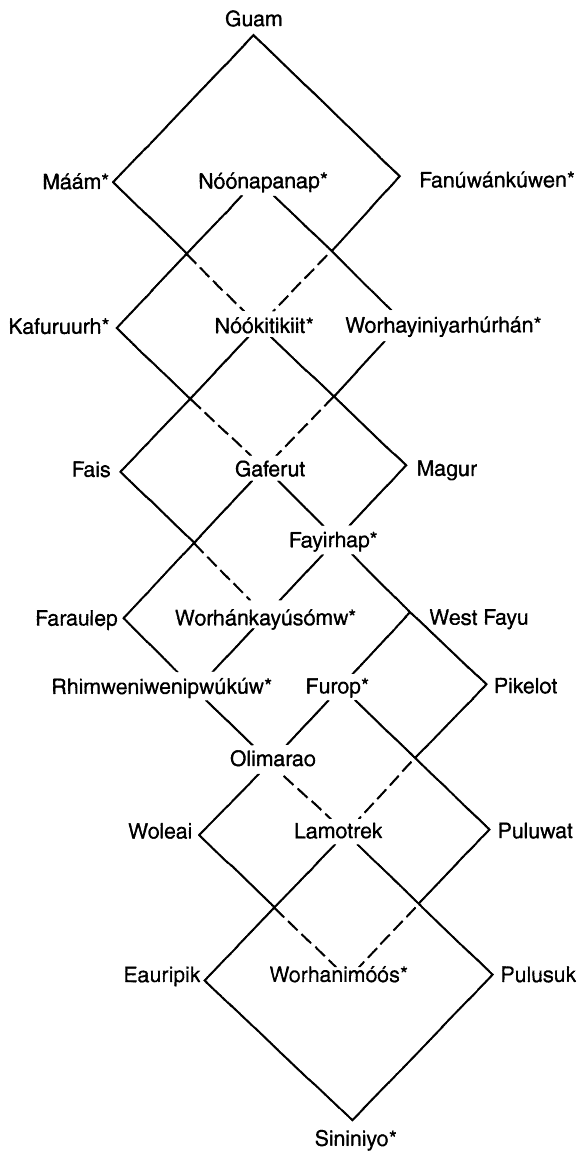


FIG. 13.21. OVERLAPPING TRIGGERFISH DIAGRAM. This overlapping series of seven triggerfish is offset laterally to take into account that Carolinian Lamotrek Atoll is to the east of the course from Guam in the Mariana Islands to the Carolinian atolls of Gaferut and Olimarao. Where no islands are at or near the four points of the fish, navigators have used reefs, shoals, living seamarks, and even imaginary islands to fill out the diagrams. These are indicated by an asterisk after the name and are as follows.
Triggerfish 1: Máám (unidentified object); Nóónapanap (big swells); and Fanúwánkúwen (mythical island).
Triggerfish 2: Kafuruurh (mythical island); Nóókitikiit (small swells); Worhayiniyarhúrhán (unidentified reef with particular living seamarks).
Triggerfish 3: Fayirhap (upside-down reef).
Triggerfish 4: Worhánkayúsómw (unidentified reef).
Triggerfish 5: Rhimweniwenipwúkúw (reef with head curving); Furop (Rainbow runner [*Elagatis bipinnulatus*])
Triggerfish 7: Worhanimóós (unidentified reef); Sininiyo (seed of *Barringtonia* sp.)
After Tomoya Akimichi, "Triggerfish and the Southern Cross: Cultural Associations of Fish with Stars in Micronesian Navigational Knowledge," *Man and Culture in Oceania* 3, special issue (1987): 279–98, esp. 287 (fig. 6).

jects over the horizon or thinks about a voyage in the abstract, he normally switches to a plan view–looking at his chart as though gazing down on the ocean from a great height, visualizing the fixed islands and continents and his vessel's progress over the surface of the sea.

In contrast, the Carolinian navigator employs a horizontal perspective even for objects he cannot see. Looking outward from his craft with his mind's eye, he visualizes the destination island approaching the canoe and pictures other islands moving past his vessel. This is not because he is incapable of assuming the top-down perspective of modern navigation and cartography. As reviewed at the beginning of this chapter, navigators from the Carolines and other parts of the Pacific were able, when asked by European explorers, to outline the arrangement of islands and archipelagoes within their own sailing ranges. Furthermore, this perspective is embedded in a Carolinian myth about how a spirit revealed navigational knowledge to Inosagur, the daughter of a chief of Pulap Atoll, to thank her for feeding him. The grateful spirit put Inosagur in a small coconut tree and by magic made it grow until it reached above the clouds. She then could see all the islands, all the reefs, banks, and shoals, and all the forms of "sea life" spread out below her. After Inosagur had memorized the rising and setting star points under which all these places lay, the spirit shrank the tree so that she could return to earth. Later, following the spirit's directions, she taught her firstborn son how to navigate, and he in turn taught the art to her second son, thus founding the two "schools," or traditions, of navigation extant in the Carolines, which are named Fanur and Wareyang after Inosagur's sons.[74] Yet it remains that Carolinian navigators do not employ this view from above when dead reckoning but prefer the horizontal perspective of looking outward from the canoe.

To envision the progress of a voyage, before leaving the navigator picks a "reference island" on one side or the other of the course line that will, in his conception, move past the canoe as he sails it toward the destination island. (When no single island happens to be placed in the right position, he may employ two reference islands in succession.) In Satawalese this reference island is called *lu pongank,* which translates as "in the middle and athwart."

74. Thomas, *Last Navigator,* 85 (note 53). On these two schools, Alkire comments: "These two 'schools' of knowledge are referred to as Masts (*gaich*). In answer to a question of 'which Mast do you know?,' the navigator will reply either *faluch* or *wuriang,* terms which refer to the legendary founders of each. There seems to be little difference in the essential navigational techniques learned in the two schools, but there are different restrictions associated with navigators of each" ("Systems of Measurement," 41 [note 53]).

Typically a reference island is a low atoll that even in daylight gives no direct visual clue of its presence until the tops of the highest coconut palms begin to poke above the horizon when the island is ten to twelve miles away. Since it usually lies several times that distance off to one side or the other of the course line, during a crossing the navigator never sees the reference island. Nonetheless, he mentally tracks its changing bearings, although exactly how he accomplishes this feat is most difficult to grasp.

Let us begin with a brief verbal description of the process. Once the voyage begins and, in the navigator's way of thinking, the reference island starts moving past the canoe, the navigator conceptualizes the progress of the voyage in terms of the reference island's bearing moving under the horizon from one compass point to another. At any time during the voyage he can therefore picture his position in terms of how far the reference island has moved through the compass points. When he reckons that the reference island has moved to where it is almost under the final compass bearing of the memorized series for the voyage, he knows that the destination island should be visible or should soon come into sight.[75]

To further explain this dead reckoning system to readers who find the concept of moving islands utterly alien, Gladwin and other analysts have diagrammed it, but not from the Carolinian perspective of a navigator looking outward from his canoe toward an unseen and moving reference island. Instead, they have taken a plan view, mapping the canoe, islands, and compass bearings as though seen from above. Gladwin diagrammed how bearings drawn from the successive star compass points through the reference island to the course line divide that line into cognitively manageable segments, or *etak* as they are known on Puluwat and Satawal (fig. 13.22). In such a diagram, the reference island is shown as fixed in one place, and the viewer is required to imagine the canoe moving along the course line from which, at successive intervals, the reference island bears in the direction of one after another of a series of star compass points.

In Thomas's more recent study of navigation on Satawal, he similarly illustrated this process of segmenting the course line with a diagram of an actual sailing route, the fifty-five-mile crossing between Satawal and West Fayu, a small uninhabited atoll north of Satawal that the Satawalese often visit to fish and hunt turtles (fig. 13.23). For this crossing Lamotrek, an atoll thirty-five miles west of the course line, serves as the reference island the navigator employs to keep track of his canoe's progress by mentally segmenting the voyage into six *etak*. At the start off Satawal, Lamotrek lies in the direction of the compass point of setting γ Aquilae. As the canoe heads northward toward West Fayu, the bearing of Lamotrek shifts counterclockwise through the compass points. When the navigator estimates that the reference island bears in the

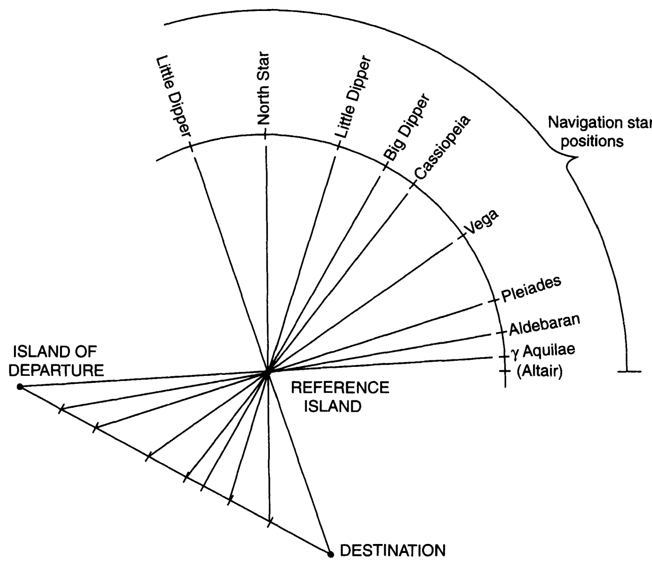


FIG. 13.22. GLADWIN'S MODEL OF *ETAK* DEAD RECKONING. Carolinian navigators dead reckon by mentally sighting over a reference island to one side of the course line between two islands, then visualizing their progress along that course line by estimating how the bearing from the canoe to the reference island shifts from one star compass position to another, thereby cutting the course line into conceptually manageable segments called *etak*. Even though the reference island is too far away to be seen, or otherwise sensed, at any time during the voyage, the navigators envision how its bearing shifts as the voyage progresses and thus are able to keep track of their progress.
After Thomas Gladwin, *East Is a Big Bird: Navigation and Logic on Puluwat Atoll* (Cambridge: Harvard University Press, 1970), 185.

direction of the next compass point, setting Altair, the first *etak* has been completed. As the voyage proceeds, the bearing of the reference island moves successively to the setting points of β Aquilae, Orion's Belt, Corvus, Antares, and Shaula to segment the voyage into five more *etak* until the canoe is within range of West Fayu.

On this particular crossing, the first and last segments created by the reference island bearings happen to coincide with what Satawalese call the "*etak* of sighting" in that the departure and target islands can be seen once the canoe is within these segments, and the second and second to last segments similarly coincide with the "*etak* of birds" in that they mark the normal flight limit of land-nesting birds.[76] However, bird and land sighting ranges do not always correspond with the successive bearings of reference islands. When, for example, the reference island is more distant from the course line, the limits of the *etak*

75. Thomas, *Last Navigator,* 77–84; cf. Gladwin, *East Is a Big Bird,* 181–89 (note 1); Lewis, *We, the Navigators,* 173–79 (note 4).

76. Thomas, *Last Navigator,* 80, and Gladwin, *East Is a Big Bird,* 188.

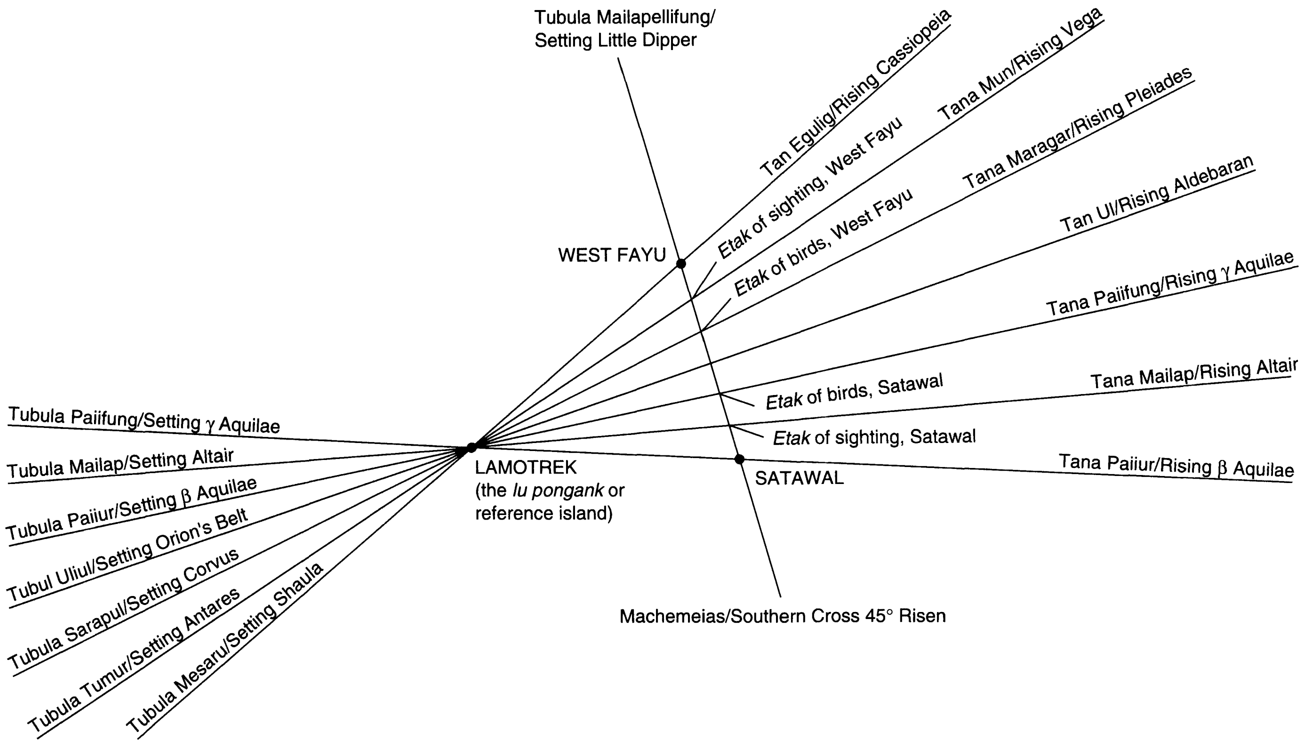


FIG. 13.23. *ETAK* RECKONING BETWEEN SATAWAL AND WEST FAYU. In the voyage pictured here from Satawal to West Fayu, islands about fifty-five miles apart, Lamotrek serves as the reference island, the changing bearings of which cut the voyage into six *etak*. On this particular route the first and last segments are equivalent to the *etak* of sighting (the farthest distance at which a low island in question can be seen), and the second and second to last segments are equivalent to the *etak* of birds (the usual limit at which land-nesting birds can be seen fishing out to sea). On routes with longer or shorter *etak* this would not be so.
After S. D. Thomas, *The Last Navigator* (New York: Henry Holt, 1987), 79.

formed by the changing bearing of the reference island surpass the limits for sighting land and land birds fishing out to sea.

Although this method of diagramming the *etak* system from above may fit Western cartographic conventions, it still leaves unanswered the fundamental question raised by the verbal description of dead reckoning as conceived by the navigator: If the navigator cannot see the reference island at any time during the voyage, how does he know when it moves from one compass point to another? From a Western navigational perspective, it is tempting to think that the resultant *etak* segments must be units of measurement like nautical miles or marine leagues, albeit longer. But such reasoning founders on the unequal length of these segments, which (depending on the distance of the reference island from the course line and its position between the departure and destination islands) can vary enormously from crossing to crossing or even within a single crossing. Contrary to the impression given by the equal or near-equal spacing shown in Thomas's diagram, figure 13.23, even when the reference island is at right angles to the midpoint of the course line, *etak* segments vary in length during a voyage, starting long at the beginning, becoming shorter toward the middle, and then lengthening toward the end. Variance between the length of the inner and outer segments increases the closer the reference island is to the course line and becomes progressively more skewed to one side or the other the farther the reference island lies off the midpoint of the course line. (The unequal spacing of *etak* segments shown in figure 13.22 is also a function of Gladwin's use, following Goodenough's precedent of actual, and therefore unequal, star bearings to denote the compass points.)

Cognitive anthropologist Edwin Hutchins has proposed that to understand how the navigator tracks the unseen reference island we need to go back to a point that Sarfert stressed in his 1911 study but that has subsequently been ignored: the navigator conceives of the horizon under which the reference island moves as a straight line, not a segment of a circle.[77] Therefore, as Hutchins points out, the horizon:

> becomes a line, parallel to the course steered, on

77. Sarfert, "Zur Kenntnis der Schiffahrtskunde," 135 (note 53).

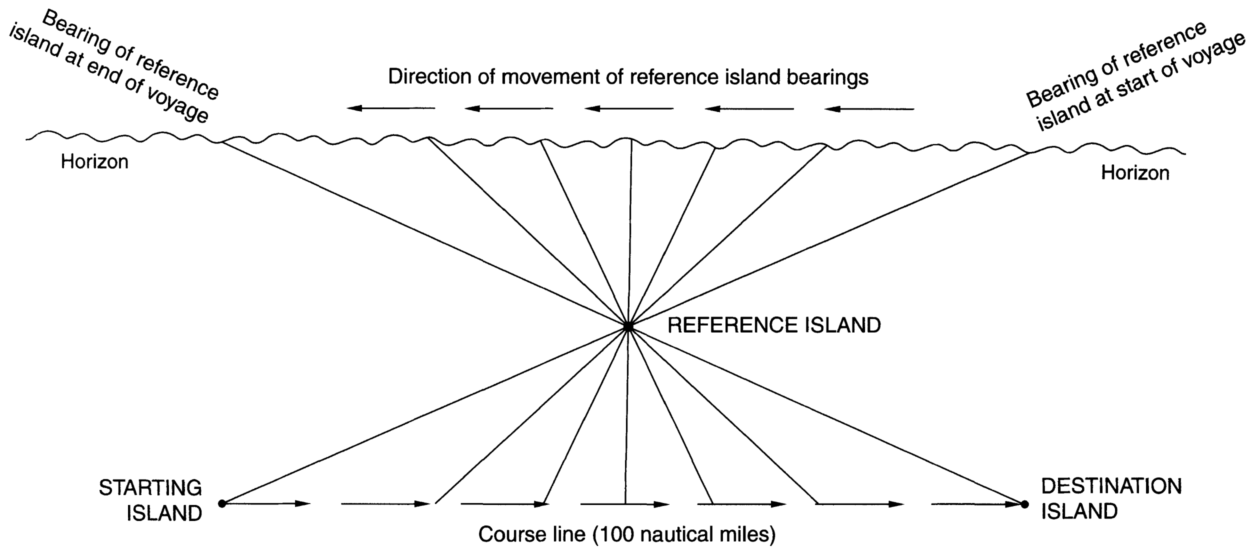


FIG. 13.24. *ETAK* DIAGRAM OF A VOYAGE ASSUMING A STRAIGHT HORIZON. By envisioning the horizon as straight, as it appears to the navigator looking outward from his canoe, rather than curved as it appears when seen from a great height, it becomes apparent that the navigator's visualization of the reference island's movement from one compass point to another models the actual movement along the course line, albeit reciprocally in terms of compass bearing.

> which the progress of the reference island from initial bearing through a set of intermediate bearings to the final bearing is exactly proportional to the progress of the canoe from the island of departure across the sea to the goal island. . . . the imagined movement of the *etak* reference island just under the horizon is a complete model of the voyage which is visualizable (but not visible) from the natural point of view of the navigator in the canoe.[78]

Figure 13.24 views from above a crossing between two islands separated by one hundred miles in which the reference island lies directly off the midpoint of the course line. A view of the horizon as seen from the canoe is added to illustrate how the navigator's visualization of the reference island's movement from one compass point to another models the actual movement of the canoe along the course line, albeit reciprocally in terms of compass bearings. With this in mind, and again with Hutchins as our guide, we are now in a position to propose an answer to the riddle of how the navigator judges the reference star's movement from under one compass point to another. Like experienced yachtsmen, canoe navigators can judge how fast they are moving by watching the water flowing past or just listening to its rush along the hull. But instead of converting these sense perceptions into so many knots (nautical miles per hour) and then multiplying that figure by the number of hours sailed to estimate how many nautical miles they have traveled in a particular period, they envision the movement of their vessels in a way that is consonant with their view of the starry horizon from the canoe. Judging from what Tupaia and several other navigators told Cook and other early explorers, Tahitian navigators estimated their progress in terms of a "sailing day" or portions thereof. Perhaps because of the relatively dense distribution of islands in the Carolines and the fact that most are atolls that cannot be seen until you are almost upon them, the navigators there developed their elegant way of visualizing the advance of their canoes toward a destination. By translating their perceptions of speed and time–honed through long experience in sailing through the islands–into angular distance traced by an invisible island along the horizon, they can mentally plot the movement of their canoes from one low coral island to another with a precision not attained in Western navigation until the development of accurate distance and time measuring devices and then more sophisticated instrumentation.

A way to portray on paper how a Carolinian navigator visualizes *etak* plotting in terms of time intervals is to forsake our usual view from above and adopt solely the perspective of looking outward from the canoe to the horizon. Figure 13.25 plots in terms of time intervals the star compass points as they would appear to the navigator sailing along the course line illustrated in the preceding figure at a steady speed of just over four knots, a rate that would enable a canoe to make the one-hundred-mile passage in twenty-four hours. Although the bearings are de-

78. Edwin Hutchins, *Cognition in the Wild* (Cambridge: MIT Press, 1995), 65–93, quotation on 84. See also Hutchins's "Understanding Micronesian Navigation," in *Mental Models,* ed. Dedre Gentner and Albert L. Stevens (Hillsdale, N.J.: Lawrence Erlbaum, 1983), 191–225.

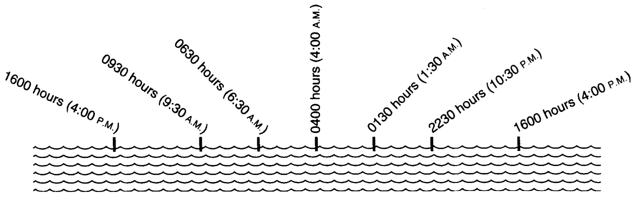


FIG. 13.25. JUDGING DISTANCE BY SAILING TIME IN THE *ETAK* SYSTEM. This diagram looks at the same situation illustrated in figure 13.24, but solely from the perspective of the navigator looking outward toward the horizon and judging the passage of the reference island from one point to another in terms of his canoe's speed converted to time intervals. This diagram assumes that the departure and destination islands are separated by one hundred nautical miles and that the canoe sails at a steady four knots. Thus, at regular intervals, denominated by time periods similar to those given here in English, the navigator judges that the *etak* passes from one star compass point to another, completing successive *etak* segments envisioned as of equal length along the course line and along the straight horizon. The navigator would, of course, adjust his time estimates according to his perceptions of the canoe's speed and also the effect of current.

nominated in terms of hours, the traditional navigator would employ such categories as late afternoon for 4:00 P.M., just after sunrise for 6:30 A.M., and so on. And he would, of course, have to adjust his estimate of when each succeeding compass point is reached according to his judgment of the sailing speed at that time.

Since the reference islands remain invisible to the navigator throughout a voyage, it is not surprising that imaginary places are used as points of reference on routes for which there is no island appropriately placed along one side or other of the course. For example, since there are no conveniently placed islands to serve as references for the entire length of the four- to five-hundred-mile voyages between the Carolines and the Marianas, navigators employ conventionally located "ghost islands" to plot their progress. The crossings between these archipelagoes illustrate how, even though this dead reckoning system may have been developed, or at least perfected, among the relatively closely spaced islands of the Caroline group, it can be adapted for longer voyages–even those over two thousand miles.

When in 1976 the Satawalese master navigator Mau Piailug guided *Hōkūle'a* from Hawai'i to Tahiti, we realized that the geography of the eastern Pacific was totally beyond his experience and that we therefore would have to brief him on the location of the islands and expected wind and current patterns. This did not violate our experimental protocol, since we were not attempting to replicate a discovery voyage. Instead, we wanted to recreate a voyage between an already settled Tahiti and Hawai'i, such as one navigated by a Hawaiian or Tahitian voyager who had already made the crossing and was therefore familiar with the distribution of islands along the route and the environmental conditions likely to be encountered. We therefore showed Mau large-scale charts of the eastern Pacific to acquaint him with relative locations of Hawai'i, Tahiti, and the other islands and discussed with him the pattern of winds and currents along the course line.

Once we were under way, Mau used the Marquesas Islands, 750 miles northeast of Tahiti and about 400 miles east of the course line, as his *etak* reference island. Even though this voyage took Mau into seas where he had never before sailed and was five times longer than any previous crossing he had made, he was able to adapt his system with impressive accuracy. After thirty days at sea he told us we would soon see the Tuamotu Atolls just to the north-northeast of Tahiti, and that if we kept sailing we would see Tahiti the next day. That night we made landfall on Mataiva, the westernmost atoll of the Tuamotu chain. After a short stay there, we set sail for Tahiti, sighting the island after a little less than a day's sailing.[79]

So far this discussion of Carolinian dead reckoning has focused only on situations when a canoe sails freely with a fair wind blowing across the course line. When the wind blows from the direction of the destination island, forcing a canoe to tack back and forth across the wind, navigators can use a variation of *etak* reckoning in which the destination island becomes the reference island as well. To explain how this is done, Gladwin has offered a simple diagram in which the departure island (A) lies due west of the destination island (B) and the wind is blowing directly from the east against the direction of travel (fig. 13.26). In this situation, island B, which lies under the rising point of Altair, serves as the navigator's reference island during tacking as well as being his destination. The diagram shows the first tack being made toward the north-northeast. As the canoe sails in that direction, the navigator visualizes its progress on that tack in terms of the bearing to island B moving from under Altair to β Aquilae, then to Orion's Belt, and finally to Corvus. At this point he puts his canoe on the other tack, sailing south-southeast until he judges that island B is under the Pleiades. Then he again tacks north-northeast and so on until, after successively shorter tacks between the bearings of Corvus and the Pleiades, the canoe reaches its destination. Thomas, who in his book presents a series of dead reckoning diagrams of actual courses that require tacking, reports that navigators consider upwind voyages to be navigationally easier than downwind ones. This is because in tacking back and forth across a rhumb line course to the target island, there is little chance they can

79. David Lewis, "Mau Piailug's Navigation of Hokule'a from Hawaii to Tahiti," *Topics in Cultural Learning* 5 (1977): 1–23, and Finney, *Hokule'a* (note 48).

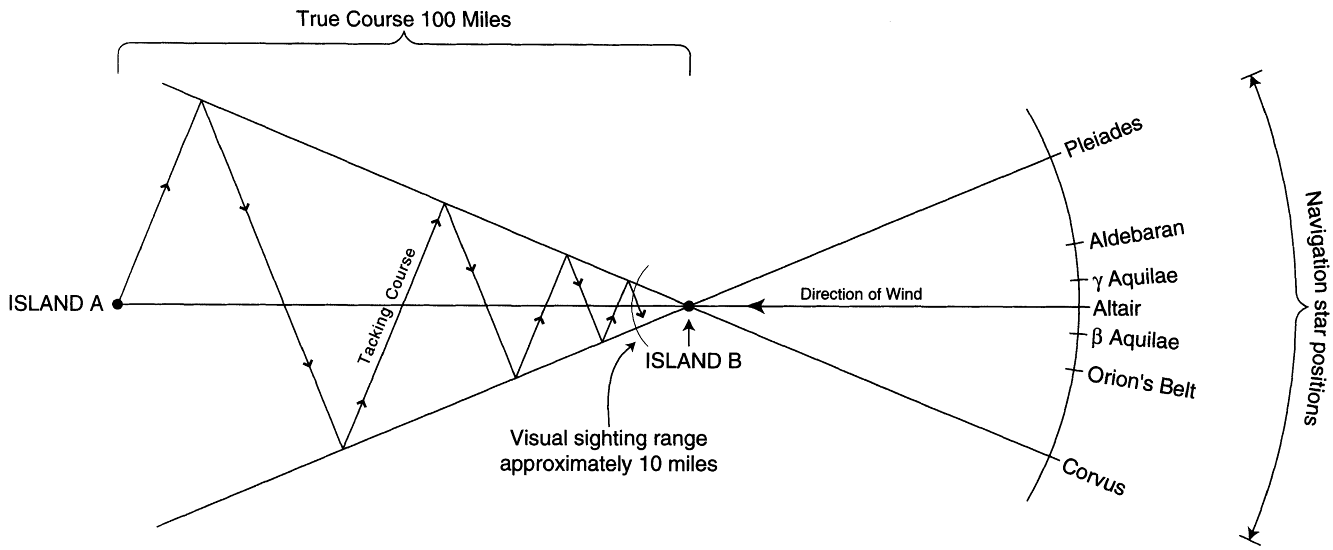


FIG. 13.26. DEAD RECKONING WHEN TACKING DIRECTLY UPWIND. In the Carolinian system, when tacking directly upwind toward an island, the latter becomes the reference island for dead reckoning as well as the destination. In this hypothetical case, the navigator is sailing directly upwind from island A to island B, which lies under the star compass point marked by rising Altair. He first tacks north-northeast until he estimates that island B lies under Corvus. Then he tacks south-southeast, sailing until he estimates that island B is under the Pleiades. At this point he tacks back north-northeast, and then again south-southeast, and so on, making shorter and shorter tacks until the canoe reaches its destination.
After Thomas Gladwin, *East Is a Big Bird: Navigation and Logic on Puluwat Atoll* (Cambridge: Harvard University Press, 1970), 191.

sail past without spotting it directly or indirectly through sighting land birds fishing around it.[80]

Piloting by Swell Pattern Disruptions in the Marshall Islands

Marshall Island navigators took the common Oceanic practice of judging when an island is near by the changes it causes in the ocean swells around it and developed this skill into a highly sophisticated sensing system. Although like other Oceanic navigators they employed the stars for orientation and initial course setting, for actually finding their way among the many islands of their twin-chain archipelago the Marshallese focused on detecting islands still below the horizon by the way they reflected, refracted, or diffracted the deep ocean swells. As distinct from deep sea navigation, the act of guiding a vessel in harbors, through channels, and along a coast by reference to landmarks, soundings of the bottom, and more recently by radar images of the land is known as pilotage. Similarly, the Marshallese technique of finding their way by using disruptions in the swells to sense the islands around them can also be called pilotage. With the demise of interisland canoe travel in the Marshalls after World War II, this art of piloting by the swells is apparently seldom practiced, and I will use the past tense in describing it.[81]

To represent the major swell patterns, and the ways the islands disrupted these patterns, Marshallese navigators made the stick charts that have so intrigued scholars of the development of cartography.[82] Although these charts have fallen out of use, copies are still being made as decorative items or for sale to tourists. Fortunately, a number of stick charts collected a century or so ago can be found in museums around the world (appendix 13.1), and there are also several descriptions of how these were employed in the Marshallese navigational system. Before drawing

80. Gladwin, *East Is a Big Bird,* 189–95 (note 1); Thomas, *Last Navigator,* 276–82 (note 53); and Hutchins, "Understanding Micronesian Navigation," 220–23 (note 78).

81. If the attempt now under way to revive canoe voyaging in the Marshalls succeeds, it is possible that swell pilotage could also be reactivated, particularly since there are many older Marshallese who still know the principles and could teach them to young sailors. In 1992, canoe makers from the Marshallese atoll of Enewetak (Eniwetok) built the first interisland sailing canoe to be constructed in more than three decades and shipped her to the island of Aitutaki in the Southern Cooks. At the same time, we sailed *Hōkūle'a* to Aitutaki to join the Marshallese canoe and a small double canoe built on Aitutaki for the sail 140 miles south to the island of Rarotonga. This sail was planned as part of a gathering of reconstructed canoes at the Pacific Arts Festival then being celebrated there. After several weeks at Aitutaki, the three canoes set sail together for Rarotonga, but they became separated after several hours as each took a slightly different course. Upon reaching Rarotonga, we learned to our delight that the navigator of the Marshallese canoe, a man in his early seventies, had been able to keep his vessel on course during the cloudy, squally night and the overcast morning that followed by orienting himself on the disruptions to the swell pattern caused first by Aitutaki, then by Rarotonga as they neared that island.

82. See note 3 above.

on these sources to describe this system of pilotage, however, we first need to consider the oceanic environment of the Marshall Islands where this system was developed, the nature of the ocean swells it was based on, and how Marshallese navigators interpreted the disruptive effects of islands standing in the paths of these swells.

The Marshall Islands are composed of some thirty-four atolls arranged in a double row, each row stretching roughly from southeast to northwest for over five hundred miles. The two chains extend from just under 5° north to over 12° north latitude, meaning that most of them lie in the "doldrums," the region between the northeast and southeast trade winds zones, characterized by seasonal calms and light winds. The northeast trade winds often extend southward and blow across the two chains from November to the end of June, but the Marshallese apparently avoided interisland sailing then because of the difficulty of reading the underlying swell patterns beneath the wind-whipped surface of the sea. Instead they preferred to sail from July through October, when the surface of the sea typically is only slightly ruffled by light southerly and variable winds, so they could easily discern undulations of swells generated from far away and could pilot their canoes by the patterned ways the islands disrupted these.[83]

According to Marshallese sailors, the islands up to about 9° north are exposed to the strong eastward flow of the equatorial countercurrent, while those to the north of that are usually bathed by the somewhat weaker westward flowing north equatorial current.[84] Neither of these flows is a steady, monolithic current, however. The Marshallese consider the countercurrent to be composed of separate narrow streams, each with an independent flow that may at times approach three knots and at other times may hardly be perceptible. This variability, increased by changes in velocity and direction as the current streams squeeze through the gaps between atolls, made it difficult for navigators moving up or down the chain across the various current streams to estimate how these displaced their canoes to one side or the other of the course line. For example, on an overnight voyage from one atoll to another, misjudging a current flowing at two knots could take a canoe so far off course that the next day it would pass the target island out of sight range. This circumstance, plus the clarity with which the ocean swells may be seen and felt during the light weather sailing months, probably goes far toward explaining why the Marshallese navigators focused so much on sensing land masses through disruptions in the swell patterns.

The deep ocean swells the Marshallese used to navigate are ultimately generated by the wind, but not the local wind blowing over the ocean where these swells are being observed. That portion of the wind's energy that is transmitted to the surface of the ocean produces, to use common nautical terminology, first small ripples and then larger and larger waves, which are cumulatively called a sea. As this wind-driven sea travels from its generating area, it eventually produces the regular, deep ocean swells. To the physicist, the ripples, waves, sea, and swells are all examples of wave transmission of energy. In this discussion of Marshallese pilotage, however, I will avoid the term "wave," lest readers think I am referring specifically to local wind waves or to waves breaking on a beach, and use the term "swell" to emphasize the distantly generated, regular character of the undulating surface of the sea that navigators monitored in piloting their canoes.

The first published notice about this unique piloting system appeared in the 1862 report of a resident missionary,[85] and not until the late 1890s was it comprehensively described. That is when a naval officer, who signed his essay "Captain Winkler of the German Navy," became so intrigued by the stick charts and the navigational principles behind them that he made a major effort to convince the secretive navigators to share their knowledge. The following summary on Marshallese pilotage is drawn primarily from Winkler's essay, from a monograph on Marshallese culture by the anthropologists Augustin Krämer and Hans Nevermann based on their fieldwork in the islands before World War I, and from more recent analyses by anthropologist William Davenport and other interpreters.[86]

According to Winkler, the Marshallese recognized four main swells: *rilib, kaelib, bungdockerik,* and *bungdockeing*. The *rilib*, or "backbone," the strongest of the four, is generated by the northeast trade winds and is present year round, even when the trades do not penetrate as far south as the Marshalls. They considered the *rilib* to come

83. Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. 504. "Sea Charts" is a translation of Winkler's "Ueber die in früheren Zeiten in den Marschall-Inseln gebrauchten Seekarten, mit einigen Notizen über die Seefahrt der Marschall-Insulaner im Allgemeinen," *Marine-Rundschau* 10 (1898): 1418–39.

84. M. W. de Laubenfels, "Ocean Currents in the Marshall Islands," *Geographical Review* 40 (1950): 254–59, esp. 257.

85. L. H. Gulick, "Micronesia–of the Pacific Ocean," *Nautical Magazine and Naval Chronicle* 31 (1862): 169–82, 237–45, 298–308, 358–63, 408–17, esp. 303–4. A Hawaiian missionary, who like Gulick was stationed in the Marshalls, also mentioned navigating by the swells in a Hawaiian-language manuscript written in 1862–63, but it was not translated and published until 1947: Hezekiah Aea, "The History of Ebon," in *Fifty-sixth Annual Report of the Hawaiian Historical Society* (Honolulu: Hawaiian Historical Society, 1947), 9–19, esp. 16–17.

86. Winkler, "Sea Charts" (note 83); Krämer and Nevermann, *Ralik-Ratak,* 221–32 (note 39); and William Davenport, "Marshall Islands Navigational Charts," *Imago Mundi* 15 (1960): 19–26.

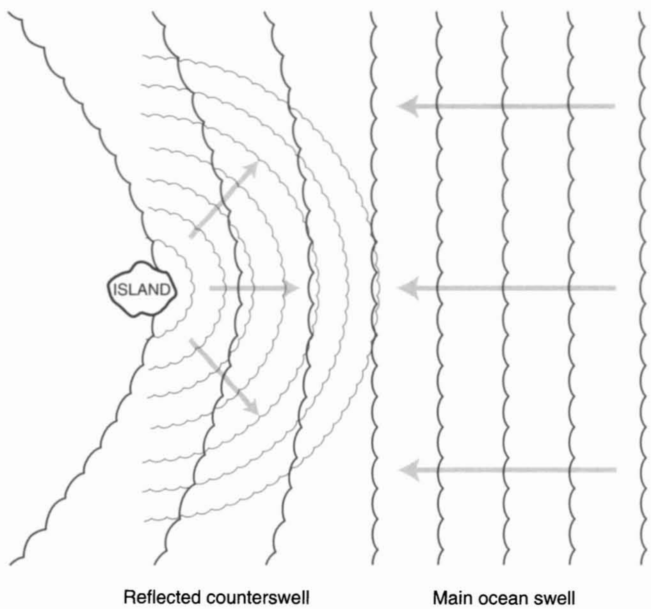


FIG. 13.27. SENSING AN ISLAND BY REFLECTED COUNTERSWELLS. Part of the energy of swells striking an island is reflected in swells that radiate back from the island, signaling to the navigator that an island barrier lies ahead.
After David Lewis, *We, the Navigators: The Ancient Art of Landfinding in the Pacific*, 2d ed., ed. Derek Oulton (Honolulu: University of Hawai'i Press, 1994), 234.

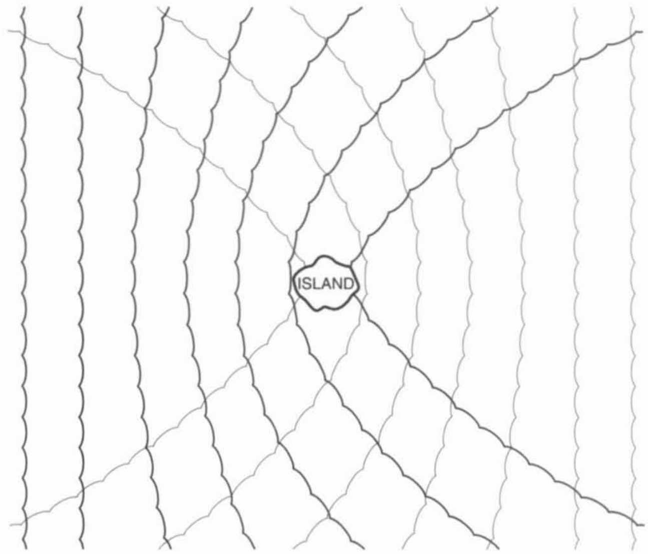


FIG. 13.28. SWELLS REFRACTING AROUND AN ISLAND. Swells also refract around an island, creating characteristic patterns of interference as they meet. This figure models only swells coming from the east and west refracting around an island and intersecting one another. The categories of refracted swells and their intersections that the Marshallese navigators abstracted from these patterns to sense the presence of an island when it cannot be seen are shown in figure 13.29.
Partially after David Lewis, *We, the Navigators: The Ancient Art of Landfinding in the Pacific*, 2d ed., ed. Derek Oulton (Honolulu: University of Hawai'i Press, 1994), 238.

from the east (*rear*), although its exact direction varies according to the angle of the generating trade winds as well as the impact of the ocean currents. The western swell, called the *kaelib,* can also be seen throughout the year, but it is weaker than the *rilib,* and unpracticed persons can detect it only with the greatest difficulty. The *bungdockerik* arises in the southwest. It can also be observed throughout the year and, especially in the southern islands, can be as strong as the *rilib*. The *bungdockeing* comes from the north and is the weakest of the four swells, felt mainly in the northern islands.[87]

Although the Marshallese navigators did not ignore the effect islands had of blocking swells and generating reflected counterswells (fig. 13.27), they seem to have concentrated primarily on the complex disruption patterns that arise out of the refraction of swells as they come in contact with the undersea slope of an island, then bend around that island and interact with swells coming from the opposite direction (fig. 13.28). A swell is refracted, or bent, when the section nearest inshore of an island slows markedly as it enters shallow water, while the section of the swell passing immediately offshore of the island is only partially slowed and that farther out in deeper water retains still more of its original speed, until the water is so deep that the speed and hence the direction of the swell are apparently unaffected.

Figure 13.29 reproduces the diagrams Winkler made to show how *rilib* (east) and *kaelib* (west) swells bend around an island and interfere with one another to provide precise information for the navigator. Where the crests of the bending swells from the east and west meet to the north and south of an island, they heap up to form a series of noticeable *bōt* (spelled alternatively *boot* or *buoj*), which translates as "knot" or "node." Encountering such a node alerted the navigator to the presence of an island nearby, and he could even roughly gauge whether it was close (when the angle between the two refracted swells is wide) or farther away (when the angle is narrow). A continuous series of such interference nodes extending out from an island forms an *okar,* or "root." "As the root, if you follow it, leads to the palm tree, so does this lead to the island," is how one of Winkler's navigator informants described the utility of the *okar.*[88] A navigator who ran into an *okar* could sail down that "root" to the island. Winkler's informants advised caution, however, telling him that *okar* were often curved to one side or the other by bands of strong currents flowing around an island. Swells coming from the north and south and bending around the eastern and western shores of an is-

87. Winkler, "Sea Charts," 493.
88. Winkler, "Sea Charts," 493.

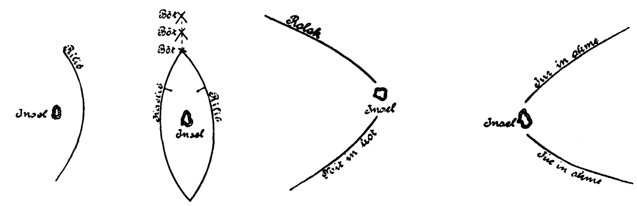


FIG. 13.29. MARSHALLESE CATEGORIES OF SWELL REFRACTION AND INTERSECTION AROUND AN ISLAND. In his study of Marshallese navigation, Captain Winkler of the Imperial German Navy drew these diagrams of how the Marshallese categorize the way swells refract and intersect around islands. The diagram on the left shows a *rilib* (swell from the east) refracting as it approaches an island. The middle diagram of a single island shows how as a *rilib* and a *kaelib* (swell from the west) refract around an island they meet to the north (and south, though not shown) and heap up to make a linear series of *bōt* ("knot" or "node"), alerting the navigator to the island before it actually can be seen. The line of such nodes extending north (or south) from an island (or east or west when refracted north and south swells meet) provides the navigator with an *okar* ("root"), which leads him directly to the island. The diagram on the right shows the refracted swells after they have passed an island, at which point they still provide the navigator with a means of sensing it. The two arms of the *kaelib* (western) swell are both called *jur in okme,* meaning "post" or "stake," in the sense that they provide obstacles that warn the navigator approaching from the east of the presence of an island. The northern and southern arms of a refracted *rilib* (eastern swell) are called, respectively, *rolok* ("something lost") and *nit in kot* ("trap" or "bird cage"), giving the sense that the navigator has overshot his target and must turn back. After Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. 493–94.

land yield the same type of information as the eastern and western swells and were most often used for navigation at the southern and northern ends of the chains.

Before a navigator reached the *okar* line, or if he had sailed through it without noticing the nodes, the way the swells were being refracted could still alert him that land was near and provide a bearing toward it. According to Winkler, refracted *kaelib* (western) swells bending around an island to the northeast and to the southeast were called *jur in okme,* which he translates as "stakes" or "posts," meaning that for the canoe approaching from the east an "obstruction" is in the way. The navigator encountering the *jur in okme* could then point his canoe in the direction of the bent swells and home in on the island at the focus of the bend. The *rilib* swells bending around an island to the northeast and southeast seem also to have been named in reference to the voyager sailing from east to west, but one who had overshot his target island and had a last chance to pick up its signature in the swells refracting past it. Those swells bending to the northwest past the island were called *rolok,* meaning "something lost," while those bending to the southwest past the islands were called *nit in kot,* "a hole," signifying a bird cage or trap that the navigator must turn out of to go back to the island.[89]

In addition to piloting by the ways swells are reflected and refracted around islands and the interference patterns set up when diffracted swells coming from opposite directions meet, Marshallese navigators were also able to use information derived from diffracted swells. Diffraction occurs when swells are interrupted or restricted by an obstacle that provides a point of departure for a new series of swells. Swells striking a breakwater with a gap in it provide a classic example of diffraction. The swells entering the opening act as a point source in generating new swells that then radiate from the gap into the harbor.[90] Similarly, when swells strike a pair of closely spaced islands, the gap between the islands can serve as a new point source for swells, which, according to Davenport, Marshallese navigators recognized from their relatively short wavelength.[91]

It is also tempting to speculate that these navigators may have learned to use a special form of wave interference that was not understood in Western science until the early 1800s, when Thomas Young performed the first diffusion grate experiments by projecting a light against an opaque barrier with two slits cut in it. The slits of such a diffusion grate act as new point sources of light that cast a pattern of light and dark bands, depending on whether the light waves emanating from the slits meet in or out of phase, an interpretation that has been crucial in confirming the wave nature of light.[92] A similar pattern of wave reinforcement and cancellation would result when a series of new swells coming from two or more narrow interisland gaps impinge on one another, causing a heaping-up effect where they meet in phase and a lull where they meet out of phase. When Marshallese navigators questioned by Krämer, Hambruch, and other Western investigators referred to particularly confused seas occurring in the vicinity of groups of closely spaced islands, they may have been referring to such interference patterns.[93]

89. Winkler, "Sea Charts," 493–94. However, Hambruch, "Die Schiffahrt," 35–36 (note 53), describes the *nit in kot* as a square area of unrefracted swells between four islands. Lewis, *We, the Navigators,* 240–41 (note 4), describes the *rolok, nit in kot,* and *jur in okme* as forming definite swell lines that extend out at about forty-five degrees from each corner of an island, where they are reinforced by swells reflecting off the island.

90. Tom Garrison, *Oceanography: An Invitation to Marine Science* (Belmont, Calif.: Wadsworth, 1993), 225–26.

91. Davenport, "Navigational Charts," 24 (note 86).

92. J. P. G. Richards and R. P. Williams, *Waves* (Harmondsworth: Penguin, 1972), 159–63.

93. Krämer and Nevermann, *Ralik-Ratak,* 226 (note 39); Hambruch,

The characteristic ways swells are disrupted by islands can be felt as well as seen. In addition to mounting a visual watch over the surface of the sea, navigators relied on their sense of balance to feel the swells by the way their canoes pitched or rolled. Raymond de Brum, a Marshallese trading boat captain who had learned to read the swells from his father, made this dual reliance clear when, in 1962, he told a reporter: "We older Marshallese people navigate our boats both by feel and by sight, but I think it is knowing the feel of the vessel that is the most important. The skipper who understands the motion or feel of the boat can sail in the dark as well as in the daytime."[94] De Brum's account is particularly valuable, if difficult to follow. Instead of taking a plan view, as did Winkler and the other Western authors we have followed here, he discussed swell navigation from the perspective of a navigator who, from a position just above sea level, watches the sea around him and feels with his body the direction, period, and strength of the swells passing beneath his canoe. Furthermore, his account ventured beyond other sources by estimating distances at which swell disruptions can be perceived: for example, he estimated that the first indications of an island can be felt from the pitching of the affected swells as far as fifty or sixty miles out and describes how the motion of a vessel changes as one gets closer to land and the swells disrupted by it.[95]

The stick charts that embody and illustrate this knowledge of swell patterns and islands were typically made from the midribs of coconut fronds lashed together to form an open framework. The locations of islands were marked by small shells tied to the framework or simply by the lashed junction of two or more sticks. Individual charts might vary so much in form and interpretation, however, that only the navigator who made a particular chart could fully interpret it. Nevertheless, Winkler and other writers agree that the charts fell into three main categories: *mattang, meddo* (or *medo*), and *rebbelib* (or *rebbelith*). Whereas the *mattang* is an abstract instructional chart for teaching the principles of reading how islands disrupt swells, the *meddo* and the *rebbelib* show actual islands and their relative if not exact positions, along with such information as the direction of the main deep ocean swells, the way these curve around specific islands and intersect with one another, and the distance from a canoe at which an island can be detected. The difference between the *meddo* and *rebbelib* is one of inclusiveness: whereas the *meddo* portrays only a section of one of the two chains of islands, the *rebbelib* includes all or most of the islands of one chain or both. Winkler's drawings of examples of these three types, along with stick chart examples, are reproduced and briefly explained below.

Figure 13.30 shows a *mattang*. Inasmuch as Winkler's description of its use is rather spare, this explanation also draws on Davenport's fuller description of the use of a similar *mattang*.[96] The points A, B, E, D, and M, where the long structural sticks of the chart intersect at the four points and at the center of the chart, can be used to represent islands. The long, straight sticks (A–D, D–B, B–E, and E–A) forming the perimeter and the straight cross sticks (v–u, t–w, r–y, and z–x) are structural, although they can do double duty to indicate swells coming from those quarters. The chart is normally aligned on *rilib*, the eastern swell; the short, vertical stick $R-R_1$ just to the right of M indicates this easterly direction (*rear*). The curved stick b–l represents the *rilib* refracting around M, with its *rolok* segment in the north and its *nit in kot* segment in the south. Similarly, the opposite curved stick a–g represents the *kaelib* or western swell refracting around M, with its two northern and southern sections both called *jur in okme*. The two other sticks curving around M (s–n and q–m) represent the refracted *bungdockeing* (north) swell and the *bungdockerik* (south) swell. Compare figure 13.31, a photograph of a *mattang*.

The intersections c and f, where the curved sticks symbolizing the eastern and western swells refracting around island M meet, represent the resultant *bōt*, or nodes of peaking, sometimes breaking water where the swells meet. The dashed line A–M–B (which is not present on the actual stick chart) indicates the *okar*, or continual line of such nodes, extending to the north and south of the island but ignoring any deviations that might be caused by crosscurrents displacing the nodes to one side or the other. In addition to alerting a navigator sailing to M from the east or the west that he is to the south or north of his target, the *okar* can be directly followed (allowing for current) by navigators moving between islands A and M, and M and B. For example, a navigator sailing from A to M would sail south along the *okar* marked by the

"Die Schiffahrt," 35–37 (note 53). However, further field research is needed to investigate whether swells moving through closely spaced islands actually generate such interference patterns anywhere in the Marshalls and, if so, whether the Marshallese navigators recognized and exploited them in their navigation. Garrison, *Oceanography*, 226, fig. 10.19 (note 90), provides an illustration of the reinforcement and cancellation of swells emanating from just such an island diffusion grate, but the legend confuses the issue both by prematurely indicating that such patterns definitely were used in navigation and by attributing the putative ability to read such diffusion grate patterns to Polynesians rather than to the Marshallese.

94. Raymond de Brum (as told to Cynthia R. Olson), "Marshallese Navigation," *Micronesian Reporter* 10, no. 3 (May–June 1962): 18–23 and 27, quotation on 18. Raymond de Brum's father, Joachim de Brum, was a Marshallese-Portuguese sea captain who was one of Winkler's primary informants.

95. De Brum, "Marshallese Navigation," 21–22.

96. Winkler, "Sea Charts," 496–97 (chart I) (note 83), and Davenport, "Navigational Charts," 22–23 (note 86). For an elegant analysis of the mathematical ideas of modeling and mapping contained in the *mattang*, see Marcia Ascher, "Models and Maps from the Marshall Islands: A Case in Ethnomathematics," *Historia Mathematica* 22 (1995): 347–70.

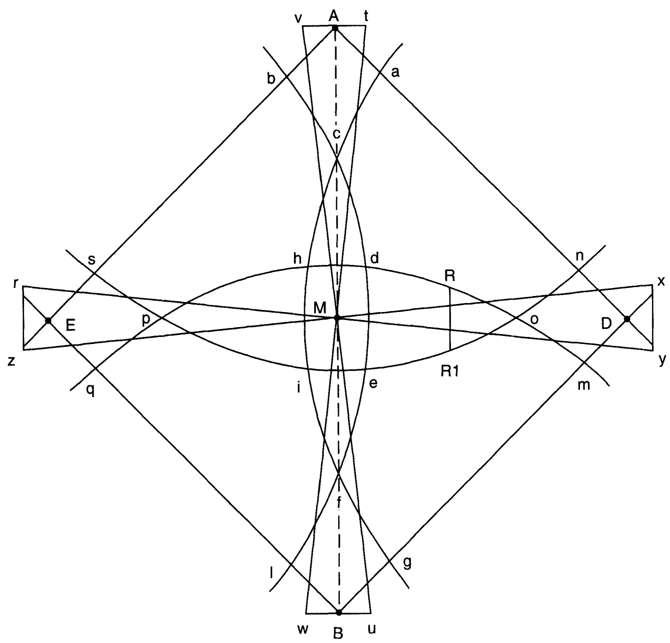


FIG. 13.30. *MATTANG:* A MARSHALLESE STICK CHART FOR TEACHING PRINCIPLES OF SWELL REFRACTION AND INTERSECTION. The *mattang* is an abstract presentation of how swells refract around an island and meet in a series of nodes. The one pictured here and the charts pictured in figures 13.32 and 13.34 were drawn by Captain Winkler from actual stick charts he studied during his 1896 investigation of Marshallese navigation. The "sticks" (actually the midribs of coconut leaves) curving around the central point M model how swells from opposite directions refract around an island and intersect (at points c, f, p, and o) to form *bōt* or nodes. The dotted line (not actually part of the chart) running between A and B indicates the *okar* or line along which nodes produced by intersecting refracted swells form.
After Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. 496.

succession of peaking nodes. When these are no longer detectable he would continue sailing south by keeping parallel to the unrefracted *rilib* or *kaelib* swells (or by keeping at the appropriate angle to them) until he picked up the line of nodes extending north from M, which he would then use to home in on the island.

Figure 13.32 illustrates a *meddo.*[97] It shows the general position of the islands in the southern part of the Ralik chain, plus a series of lines for instructional purposes. Each large dot represents an island, which is a shell lashed to the framework on the actual chart. The dot at E at the bottom of the chart stands for the island of Ebon, and the dot at A at the top stands for Ailinglapalap. The dots along the horizontal line at N, K, J, and M stand, respectively, for the islands of Namorik, Kili, Jaluit, and Mili. The sticks M–G and M–E stand for the *rilib* swell refracting around Mili. Similarly, the sticks O–A and O–E stand for the *kaelib* swell refracting around Namorik. The sticks P–Q, R–S, and T–U mark the *bungdockeing* (bn) or north swell; the sticks V–W, X–Z, and O–M mark the *bungdockerik* (bk) or south swell. Stick H–L is intended to show a south swell specifically for Mili but is placed above because there is no room to tie it below the island.

Stick K–d is intended to show a north swell for Jaluit Island, and at the same time the *jur in okme* or "post" end of the west swell refracted around Kili Island. Stick B–X represents the *rolok* or "lost course" end of the east swell refracted around the north side of an island, and stick B–Y the *nit in kot* or "bird cage/trap" end of the east swell refracted around the south side of an island at point B. The stick a–a passing through B indicates the direction of the swell from the east. The stick l–l going through C is an *ai* or distance marker for Ebon Island. Point C represents the *bōt* or node where the *rilib* (stick C–F) and *kaelib* (stick C–D) refracting around the north side of Ebon meet. Stick E–K represents the *okar* line of nodes running between Ebon and Kili islands. Compare figure 13.33, a photograph of a *meddo.*

Figure 13.34 shows a long, narrow *rebbelib.*[98] It includes all but two of the main islands of the Ralik chain, each marked in the drawing by large dots standing for a shell in the original. The framework for the central core of the chart is made by joining six long, curved sticks, three on the right and three on the left, that also represent the *rilib* (east) and *kaelib* (west) swells as they begin to bend when approaching an island obstacle. Most of the chain's islands are attached within this lenticular core. Namorik (Nk) in the southwest is attached to the core by an extension, as are Ujae (U) and Wotho (W) in the northwest. The maker did not extend the chart past Ujae and Wotho to include Ujelang and Enewetak, the westernmost atolls of the Ralik chain, perhaps because doing so would have made the chart even more unwieldy than it is. Compare figure 13.35, a photograph of the same *rebbelib.*

Winkler considers the *rebbelib* in figure 13.34 especially interesting because it shows several examples of *bōt,* or nodes of intersecting swells refracting around an island, as well as information on how far away an island can be detected. Before considering the way this information is presented, however, a caveat is in order. At the beginning of his description of the chart, Winkler warns the reader that "the position of the islands is insufficiently indicated by the mussels, as may be seen by comparison with the charts." He adds that his interpreter, who must

97. Winkler, "Sea Charts," 498–500 (chart III).
98. Winkler, "Sea Charts," 500–502 (chart IV).

have been another Marshallese navigator, objected to the placement of some of the islands and commented that some of the nodes were also misplaced. Apparently, however, such "misplacements" did not bother the chart's

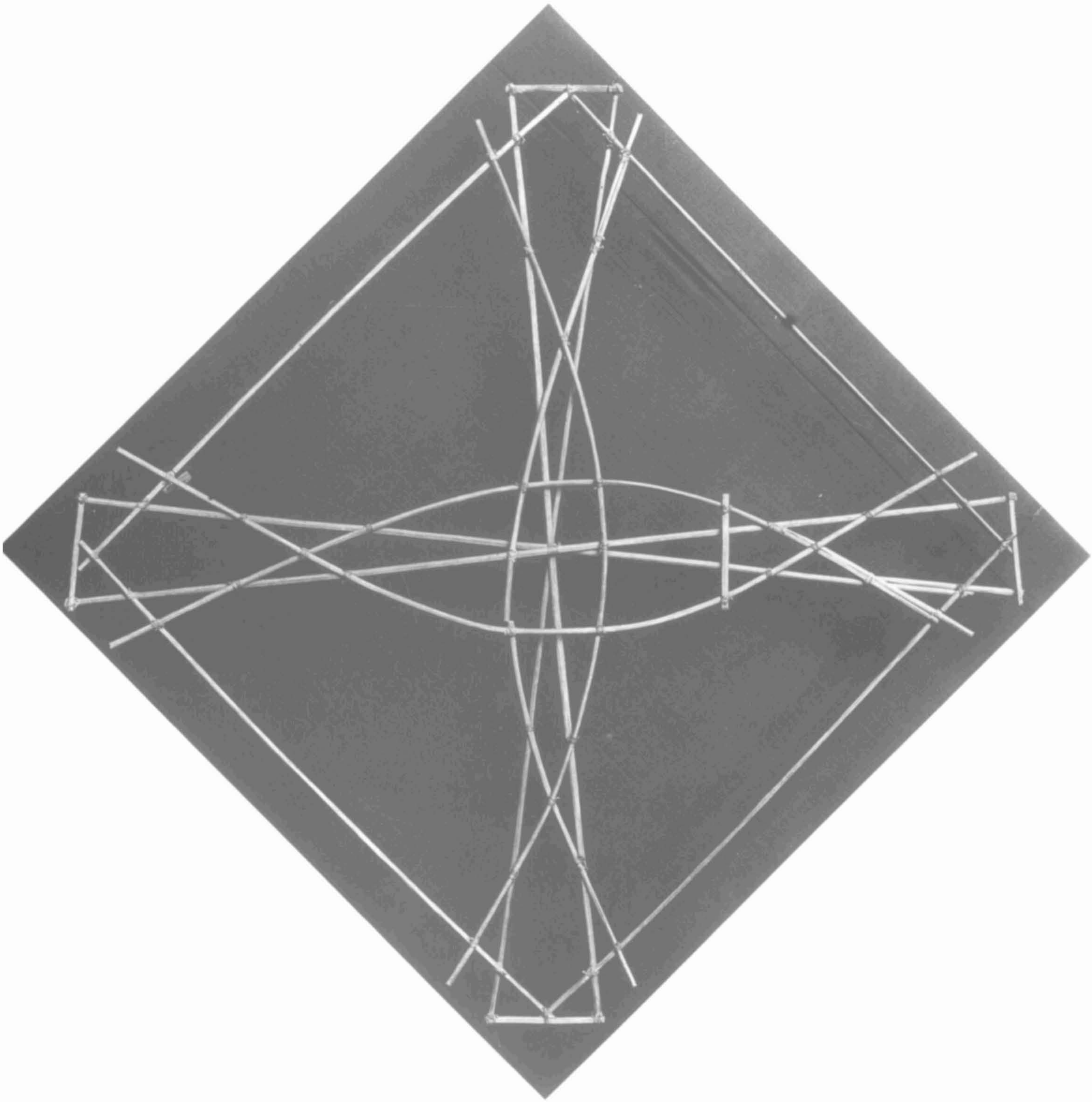


FIG. 13.31. EXAMPLE OF A *MATTANG*.
Length of the original: 78 cm (compare fig. 13.30). Photograph courtesy of the Museum für Völkerkunde, Berlin.

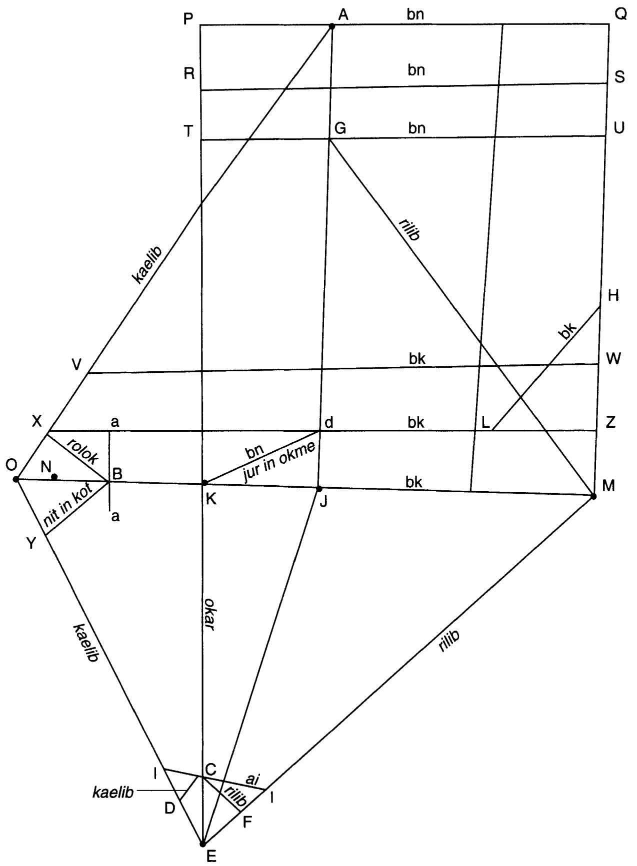


FIG. 13.32. *MEDDO:* A MARSHALLESE STICK CHART SHOWING ISLANDS AND SWELL PATTERNS IN ONE SECTION OF AN ISLAND CHAIN. The *meddo* pictured here shows the general positions of the islands of Ebon (E), Ailinglapalap (A), Namorik (N), Kili (K), Jaluit (J), and Mili (M) at the southern end of the Ralik chain, as well as directions of the main ocean swells and (for some of the islands) the characteristic intersections these swells make as they refract around an island. On an actual chart the islands represented here by the dots at points E, A, N, K, J, and M may be indicated by shells lashed onto the framework. Although the *meddo* are considered to be fairly realistic representations of island relationships, they were only used as mnemonic aids before a voyage and not consulted during it.
After Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. 499.

navigator-maker, who informed Winkler that he knew what everything stood for and "how to make them clear in their present places."[99]

The nodes along the *okar* leading from Ab (Ailinglapalap) to J (Jaluit) are shown by sticks lashed in a chevron shape indicating the intersections of refracting eastern (*rilib,* labeled r) and western (*kaelib,* labeled k) swells (r_1/k_1 and r_2/k_2) at points c_1 and c_2, respectively. Note how the chart shows the angle of intersection of the refracting swells decreasing as one moves farther from the island at the focus of the refraction. Similarly the points a_1 and a_2, and the refracting swells r_3/k_3 and r_4/k_4, indicate the line of nodes extending north from N (Namu). The four nodes indicated between the *okar* running between J (Jaluit) and Nk (Namorik) in the southwest result from the intersection of north (*bungdockeing,* bn) and south (*bungdockerik,* bk) swells instead of east and west swells. Here, however, is one of the places where the drawing and the explanation given to Winkler seem to clash: although Winkler reports he was told that the nodes are extending out from Jaluit, the direction of the chevrons formed by the intersecting swells makes the nodes appear to be extending from Namorik instead. The nodes C_1 and C_2 are focused on Ujae Island and similarly are formed by the intersection of the south and north swells indicated by the sticks bk_1/bn_1 and bk_2/bn_2.

According to Winkler, the two series of sticks–4, 5, and 6 in the north and 1, 2, and 3 in the south–that extend across the main body of the chart stand for the progressively farther "sighting distances" (*ai*) from Namu and Jaluit, respectively. According to Krämer and Nevermann, however, the terms by which Winkler labels these "sighting distances" actually stand for characteristic "currents": *djeldjelatăe,* which appears about ten miles out from an island where palm trees can be sighted; *rebukăe,* which is about fifteen miles out; and *djugăe,* which occurs still farther out, beyond all sight of land. Yet if Raymond de Brum was talking about the same phenomena when he told his interviewer about the "*jelat ai*" as a type of pitching felt about twenty miles out and the "*jeljelat ai*" as the type of pitching felt about ten to fifteen miles out, it seems likely that these "sighting distances" or "currents" actually refer to the changing nature of the swells felt aboard a canoe as it moves toward or away from an island.[100]

Because the stick charts found today in museum collections did not begin to be collected until the late nineteenth century, by which time the Marshall islanders were being visited with increasing frequency by Western ships, we must consider the possibility that these surviving examples may display Western influence. Particularly suspect are the most "maplike" charts, the *rebbelib,* which show all or most of the islands of one chain or the entire group but give very little information on swells. In his article, Winkler illustrates a *rebbelib* that includes the main islands of both chains and comments that the "tolerable accuracy" with which the navigator-maker had arranged

99. Winkler, "Sea Charts," 500.

100. Winkler, "Sea Charts," 501–2; Krämer and Nevermann, *Ralik-Ratak,* 225 (note 39); and de Brum, "Marshallese Navigation," 23 (note 94).

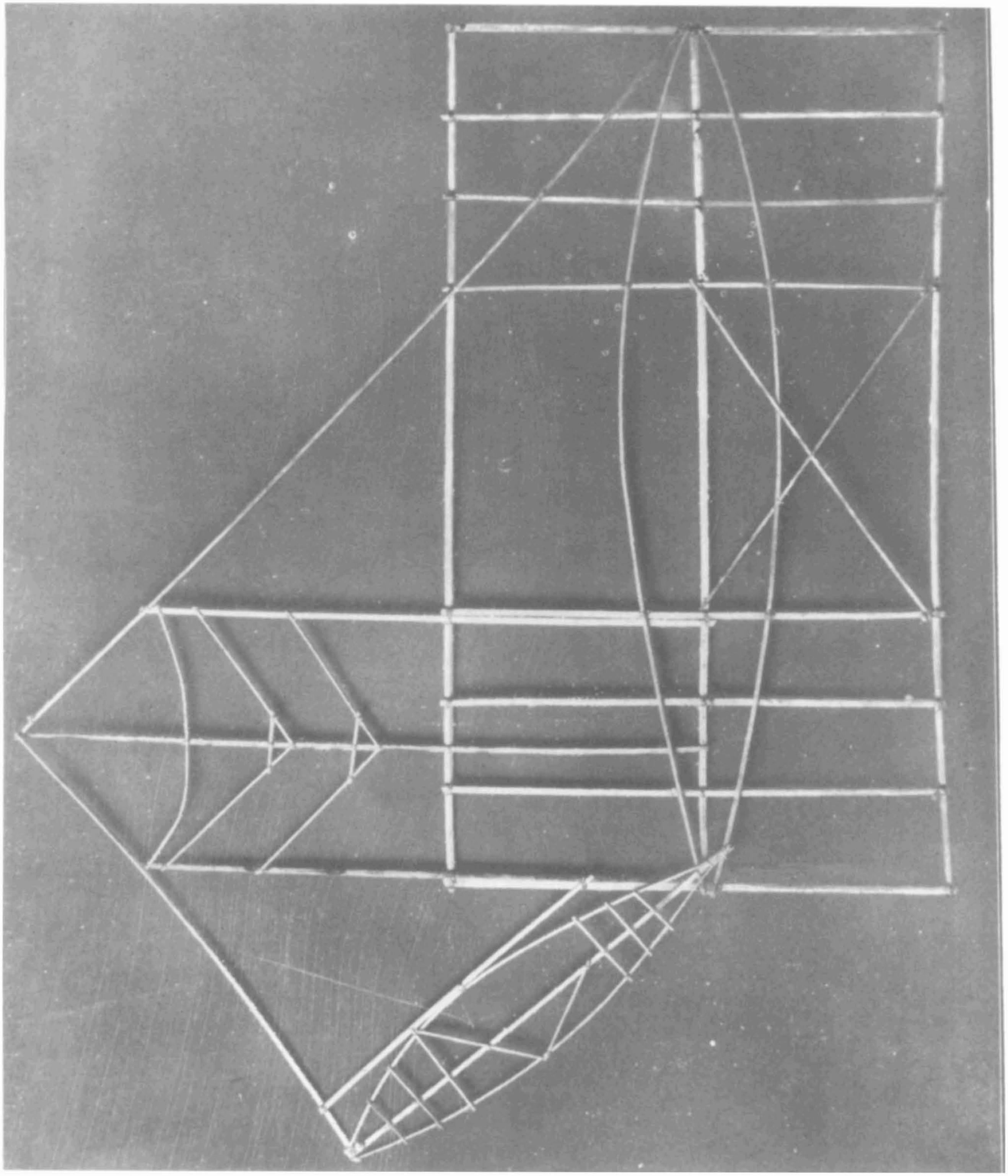


FIG. 13.33. EXAMPLE OF A *MEDDO*.
Length of the original: 160 cm. From Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899*, 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. pl. VIII.

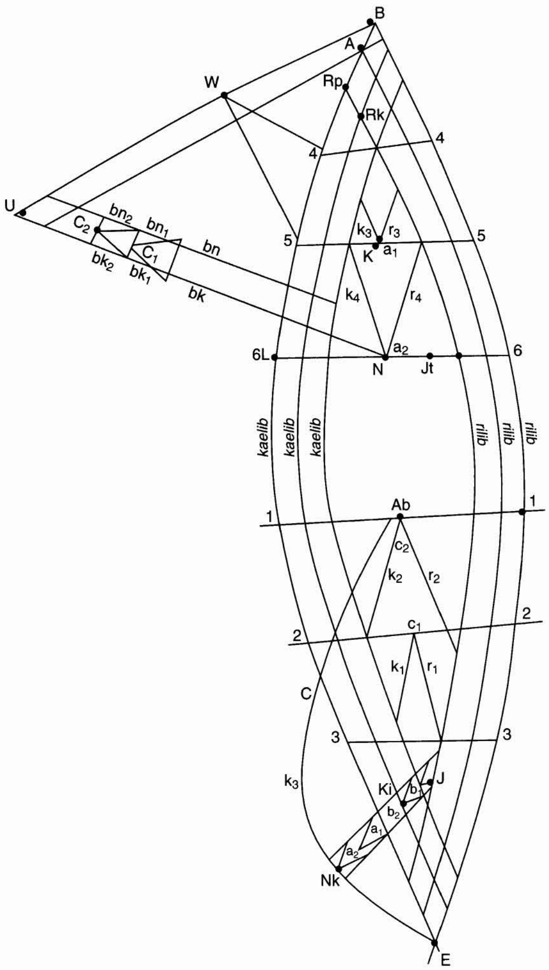


FIG. 13.34. *REBBELIB:* A MARSHALLESE STICK CHART THAT REPRESENTS THE ISLANDS OF ONE OR BOTH CHAINS. The *rebbelib* pictured here includes all but the far northwest islands (Enewetak and Ujelang) of the Ralik chain: Ebon (E); Namorik (Nk); Kili (Ki); Jaluit (J); Ailinglapalap (Ab); Jabwot (Jt); Namu (N); Lib (L); Kwajalein (K); Rongerik (Rk); Rongelap (Rp); Ailingnae (A); Bikini (B); Wotho (W); Ujae (U). The central framework of long, curving sticks also represents the refracting *rilib* (eastern) and *kaelib* (western) swells. The chevrons indicate the intersection of swells refracting around islands, and the horizontal sticks represent the distances at which different indications of an island can be detected. As with the other types of charts, the *rebbelib* were not consulted during voyages.
After Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508, esp. 501.

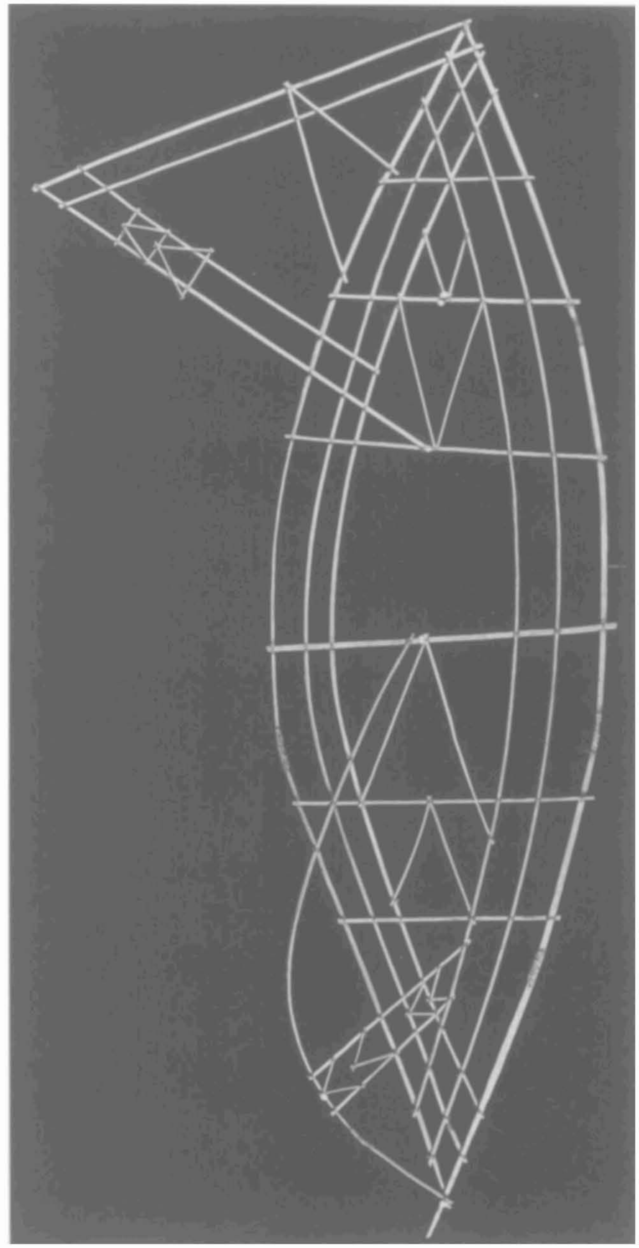


FIG. 13.35. EXAMPLE OF A *REBBELIB.* Compare figure 13.34.
Length of the original: 158 cm. Photograph courtesy of the Museum für Völkerkunde, Berlin.

the islands came about because the chart had "been prepared after an acquaintance with our own charts." [101]

This line of reasoning can be taken too far, however, as in the analysis by George Playdon, a retired U.S. Coast Guard officer who had spent some time in the Marshalls after World War II. His contention that the *meddo* and *rebbelib* were Western-influenced period pieces of only a "brief historical duration, perhaps from 1830 to 1895," and that the *mattang* must be "a simple training device of limited antiquity" because it had not spread throughout Micronesia and the rest of the Pacific, seems misinformed for several reasons.[102] First, before major European

101. Winkler, "Sea Charts," 497–98 (chart II).

102. George W. Playdon, "The Significance of Marshallese Stick

influence had reached the islands, Marshallese navigators were able to map their islands with enough accuracy to appeal to Kotzebue's discerning eye. Second, the depictions of swells, interference patterns, and island detection distances included in the *meddo* and such *rebbelib* as that of the Ralik chain (for example, figures 13.32 and 13.34) could hardly have been borrowed from Western charts, since they are unique to the Marshallese cartographic tradition. Third, the suggestion that the *mattang* must be of "limited antiquity" (ca. A.D. 1500?) because it had not been adopted beyond the Marshalls ignores the secrecy with which the Marshallese navigators guarded their knowledge of this art, as well as the difficulty of transferring to other archipelagoes techniques so closely adapted to the unique ocean swell environment of the Marshalls.

Probably more misinformation has been published about these stick charts than about any other facet of Pacific island navigation. The most frequent error is to attribute the charts and practices to the Polynesians rather than to their distant Marshallese cousins in Micronesia. Second is the notion that the charts portray currents on which the navigator guides his canoe, not the ocean swells. Third would be the assumption that a navigator took his stick charts to sea and used them in navigation as his Western counterpart employed nautical charts.

In his analysis, Davenport states categorically that the stick charts are used only "to teach navigators and possibly to store knowledge against memory loss. They are most assuredly not used to lay out courses, plot positions and bearings, or as aids in recognizing land forms as the European navigator uses his chart. Nor are they mnemonic devices to be taken along on a voyage for consultation. The Marshallese navigator carries his information in his head and does not need to rely upon a reminder."[103] Davenport based his statement on written sources dating from German times, as well as knowledgeable Marshallese living during the 1950s when he did his research. When, for example, Krämer and Nevermann discussed the *meddo,* the stick chart they considered best represents actual sea conditions and islands, they state that the navigator studies this chart only before a journey, "for it is considered scandalous to continue to consult a chart when underway." They further explain how the navigator, after having made sure the season, wind, and weather are right for a voyage, and after having checked which guiding star to use for the course, may consult his stick chart just before leaving, checking the swell patterns and intersections he will use for navigation. Once en route they, like other authors, describe how the navigator focuses intently on sensing the swells and any interference patterns made by their intersection, crouching down in the bow of his canoe to observe the surface of the sea from as low down as possible, or lying prone to feel with his whole body how the canoe is being pitched and rolled by the underlying swells.[104]

Did Oceanic Navigators Use Navigational Instruments?

Just as traditional navigators did not need to take their stick charts, outlines of their star compass, or any other type of physical map to sea with them,[105] it also seems that they did not have to employ any special navigational instruments to help them read the stars, the swells, or any other phenomena crucial to guiding their canoes. Yet various writers have proposed numerous indigenous navigational instruments–for example, sticks and water-filled canes to measure latitude,[106] and the variously drilled or etched bowls and gourds supposedly designed for finding one's way over the long Polynesian sea routes. However, no examples of such instruments can be securely identified today in museums or private collections. Furthermore, none of the texts in which the proposed instruments are mentioned and sometimes sketched seem to have been written by persons who actually witnessed them being used at sea or even examined them on land.

The most famous candidate for an indigenous navigational instrument is the "sacred calabash" of Hawai'i. In 1927 Admiral Hugh Rodman published an article in which he described how Polynesian voyagers sailing north from the South Pacific to Hawai'i sighted through holes drilled near the top of a water-filled "sacred calabash" so that Polaris came in view when it was nineteen degrees above the horizon, thus indicating that their canoe had reached the latitude of Hawai'i. In the following year, ethnologist John F. G. Stokes of Honolulu's Bishop Museum responded to Rodman's article by point-

Charts," *Journal of the Institute of Navigation* 20 (1967): 155–66, quotation on 166.

103. Davenport, "Navigational Charts," 21–22 (note 86).

104. Krämer and Nevermann, *Ralik-Ratak,* 230–31 (note 39).

105. Two other examples of mapping devices used on shore but not at sea come from the Kiribati archipelago (the Gilbert Islands), just south of the Marshalls: an outline of a canoe made of large coral fragments, which was used to teach both star and ocean swell navigational lore (Lewis, *We, the Navigators,* 228–30 [note 4]); and the beams and rafters of meeting houses, which represented the divisions of the night sky (Arthur Grimble, "Gilbertese Astronomy and Astronomical Observances," *Journal of the Polynesian Society* 40 [1931]: 197–224, esp. 220 n. 24).

106. On the sticks, see A. Schück, "Die Entwickelung unseres Bekanntwerdens mit den astronomischen, geographischen und nautischen Kentnissen der Karolineninsulaner, nebst Erklärung der Medo's oder Segelkarten der Marshall-Insulaner, im westlichen grossen Nord-Ocean," *Tijdschrift van het Nederlandsch Aardrijkskundig Genootschap, gevestigd te Amsterdam,* 2d ser., 1 (1884): 226–51. The water-filled canes are mentioned in E. Sanchez y Zayas, "The Marianas Islands," *Nautical Magazine* (London) 34 (1865): 449–60, 641–49, and 35 (1866): 205–13, 253–66, 297–309, 356–63, and 462–72, esp. 256–57 and 263.

ing out that the "calabash" in question was actually a carved wooden "traveling-trunk" of a high chief that, if filled with water to be used in the manner Rodman described, would have weighed an impractical one hundred pounds.[107] In 1947 Rodman's sacred calabash was brought up again by an American resident of Tahiti, who proposed that Tahitians may have employed a similar instrument. His proposal drew an immediate response by the famed Māori anthropologist and then director of the Bishop Museum, Peter H. Buck (Te Rangi Hiroa), who reiterated and amplified Stokes's rebuttal of Rodman.[108] Then in 1975 Hawaiian scholars Ruby Kawena Johnson and John Kaipo Mahelona published a monograph on Polynesian astronomy in which they revisited the issue with some intriguing new information.

In their monograph, Johnson and Mahelona reproduce and discuss an unpublished manuscript, "Navigation Gourd Notes." An amateur scholar, Theodore Kelsey, had compiled these notes, apparently about 1950, from the records of his conversations with an elderly Hawaiian informant, as well as from information he attributed to "foreign observers," which is perhaps a reference to the writings of Rodman, Duryea, and other enthusiasts in the quest for a Polynesian navigational instrument. According to these notes, Hawaiians made "navigation gourds" by drilling and etching gourds and binding them with lines to create holes and lines for sighting on the stars. They then used these instruments to find their way between the main islands of their archipelago and also to sail to the small, rocky islets and atolls that extend far to the northwest beyond the currently inhabited islands of the Hawaiian chain. However, Kelsey's descriptions of these devices, his crude sketches of what he thought they must have looked like, and his attempts to explain how they were used are most difficult to follow–perhaps because he was mixing the recollections of his informant with the conjectures of ill-informed "foreign observers" and did not himself understand navigational principles, modern or indigenous.[109]

Fortunately, Johnson and Mahelona also include in their work a translation of a Hawaiian text on how to mark and then employ a gourd to teach celestial navigation. The original text had been published in 1865. In reading the translation, which follows, it is useful to know that Kane and Kaneloa are major Hawaiian gods, that Wakea is the "sky father" of Hawaiian cosmology, that "the Kahiki groups" refers to the islands such as Tahiti, which lie far to the south of Hawai'i in the Southern Hemisphere, and that many of the stars named in Hawaiian cannot now be identified.

> Take the lower part of a gourd or hula drum (hokeo), rounded as a wheel, on which several lines are to be marked (burned in), as described hereafter. These lines are called "Na alanui o na hoku hookele" (the highways of the Navigation stars), which stars are also called "Na hoku-ai-aina" (the stars which rule the land). Stars lying outside of these three lines are called "Na hoku o ka lewa," i.e., foreign, strange or outside stars.
>
> The first line is drawn from the "Hoku paa" (North Star), to the most southerly of "Newe" (Southern Cross). The portion to the right or east of this line is called "Ke ala'ula a Kane" (the dawning, or the bright road of Kane); and that to the left or west is called "Ke alanui maaweula a Kanaloa" (the much travelled highway of Kanaloa).
>
> Then three lines are drawn east and west (latitudinally), one across the northern section, indicates the northern limit of the sun, about the 15th and 16th days of the month Kaulua, and is called "Ke alanui polohiwa a Kane" (the black shining road of Kane). The line across the southern section indicates the southern limit of the sun, about the 15th and 16th days of the month Hilinama, and is called "Ke alanui polohiwa a Kanaloa" (the black shining road of Kanaloa). The line exactly in the middle of the sphere (the drum, the Lolo), is called "ke alanui a ke Ku'uku'u" (the road of the Spider), and also "Ke alanui i ka Piko o Wakea (the way to the navel of Wakea).
>
> Between these lines are the fixed stars, "Na hokupaa o ka aina." On the sides are the stars by which one navigates. The teacher will mark the positions of all these stars on the gourd. Thus he will point out to his scholars the situation of Humu (Altair), Keoe (Vega?), Nuuanu, Kapea, Kokoiki, Puwepa, Na Kao (Orion), Na Lalani o Pililua, Mananalo, Poloahilani, Huihui (the Pleiades), Makalii (the twins) /sic/, Ka Hoku Hookekewaa (Sirius), Na Hiku (the Dipper), and the Planets, "hoku hele," Kaawela (Jupiter), Hokuloa (Venus), Hokuula (Mars), Holoholopinaau (Saturn), Ukali (Mercury), etc.
>
> During the nights from Kaloa to Mauli (the dark nights of the moon), are the best times for observation. Spread out a mat, lie down with your face upward, and contemplate the dark-bright sections of Kane and Kanaloa, and the navigating stars contained within them.
>
> If you sail for the Kahiki groups, you will discover new constellations and strange stars over the deep ocean, "hoku i ka lewa a me ka lepo."
>
> When you arrive at the "Piko o Wakea" (Equator), you will lose sight of the Hoku-paa (North Star); and then "Newe" will be the southern guiding star, and

107. Hugh Rodman, "The Sacred Calabash," *United States Naval Institute Proceedings* 53 (1927): 867–72, and the comments of John F. G. Stokes and Rodman in the discussion section of the *United States Naval Institute Proceedings* 54 (1928): 138–40 (both reprinted in *Journal of the Polynesian Society* 37 [1928]: 75–87).

108. "Au sujet de la calebasse sacrée des Iles Hawai," *Bulletin de la Société d'Études Océaniennes* 7 (1947): 289–91 (letter by Chester B. Duryea and response by Peter H. Buck).

109. Johnson and Mahelona, *Nā Inoa Hōkū,* 142–53 (note 46).

> the constellation of "Humu" will stand as the guide above you, "Koa alakai maluna."
>
> You will also study the regulations of the ocean, the movements of the tides, floods, ebbs and eddies, the art of righting upset canoes, "Ke kamaihulipu," and learn to swim from one island to another. All this knowledge contemplate frequently, and remember it by heart, so that it may be useful to you on the rough, the dark and unfriendly ocean."[110]

From the quotation above, it seems clear that the gourd in question was a teaching device used on land, not a navigational instrument to be employed at sea, a conclusion that is consonant with what we know about the Marshallese stick charts as well as the Carolinians' representations of their star compass and "charts" of the islands to be found along each bearing. Although the master navigators of Oceania could have gone to sea carrying engraved astronomical gourds, stick charts, sketches of a star compass, or other devices, they apparently did not. However useful such devices were in learning their craft or in refreshing their memories before a voyage, they did not have to consult them at sea. They set sail "on the rough, the dark and unfriendly ocean" with only the knowledge of the stars, winds, swells, and surrounding islands, and the principles for using these to navigate, for that was all they needed.[111]

Generally overlooked, however, in discussions about whether traditional navigators employed instruments at sea is the fact that parts of the canoe, or even the whole canoe, are used to aid navigation. Judging from my observations at sea of how the Carolinian navigator Mau Piailug and his Hawaiian colleague Nainoa Thompson pursue their skill, such canoe parts as the prow, masts, sections of the rail, the rigging, and fluttering "telltales" attached to the latter can help navigator and steersman sight on stars, track the sun, or keep aligned on the wind. Furthermore, a whole canoe can be turned into a compass rose by marking the compass points on the rails and other features, as I have seen Nainoa Thompson do to help aspiring navigators guide *Hōkūle'a.* As a steersman, I can also attest that in cloudy weather I have more than once kept *Hōkūle'a* on course by feeling the way she reacted to the regular swells passing beneath her twin hulls and keeping her aligned at the appropriate angle to them. This use of an entire canoe as a swell-gauging instrument, was, as we have seen, developed to a high art by the Marshallese navigators, who in the dark of night could feel their way to an island and even into its main pass by sensing the way the information-laden swells pitched and rolled the canoes beneath them.

Colonization, Continuity, and Connections

When some 3,500 years ago Austronesian voyagers first headed their canoes eastward beyond the Bismarck Archipelago and the adjacent islands of the Solomon group, they made a remarkable discovery. Every new island they found in the ocean expanses to the east was unpopulated. Since only they had the technology and skills required to sail so far into the ocean, the prospect of finding and settling one uninhabited land after another must have excited these seafarers, pulling them farther and farther into the ocean until all the permanently habitable islands of the whole of Oceania had been discovered and settled.

To expand over so much of the Pacific, these pioneering seafarers needed more than seaworthy canoes with efficient sail rigs and the ability to exploit seasonal wind patterns to sail where they wanted to go. They also had to be able to navigate in the open ocean and to conceptually map their discoveries. Although the archaeological record by which we trace and date the Austronesian expansion cannot tell us anything directly about their navigational and cartographic methods, that these seafarers were able to spread so far, so fast, and to maintain some communication between home islands and newly discovered ones, as well as among settled outposts, suggests that when they entered Remote Oceania they already had developed basic navigational skills. Judging from what we know of the abilities of the Oceanic descendants of these pioneering Austronesians, these skills must have included some competence in orienting and holding a course by reference to the stars, ocean swells, and winds, in dead reckoning, in sensing islands before they could be seen directly, and in incorporating newly found islands into some kind of cognitive chart.

If, as linguists and prehistorians posit, the seafaring complex that set the stage for the Austronesian expansion into Oceania originated in island Southeast Asia,[112] we

110. Johnson and Mahelona, *Nā Inoa Hōkū,* 72–73, from the following translation: Samuel Manaiakalani Kamakau, "Instructions in Ancient Hawaiian Astronomy as Taught by Kaneakaho'owaha, One of the Counsellors of Kamehameha I., according to S. M. Kamakau," trans. W. D. Alexander, *Hawaiian Annual* (1891): 142–43. Kamakau's article containing the original text was published in the Hawaiian newspaper *Na Nupepa Ku'oko'a* on 5 August 1865 in Honolulu, Hawai'i, by historian Samuel Manaiakalani Kamakau, who had based it on an interview he had conducted some years earlier with Kaneakaho'owaha, a traditional Hawaiian astronomer who had served Kamehameha I, the high chief who united all the Hawaiian islands into a kingdom during the early postcontact period from the late 1700s to the early 1800s.

111. Alternatively, some descriptions of so-called navigating gourds may have referred to devices for predicting or controlling the wind, such as the wind gourd from the Cook Islands described on pp. 458–59 above. There is a legendary account of the use of a wind gourd to control the local winds around the islands of Hawai'i, but it does not include an exact description of the device. Moses K. Nakuina, *The Wind Gourd of La'amaomao,* trans. Esther T. Mookini and Sarah Nākoa (Honolulu: Kalamakū Press, 1990).

112. Robert Blust, "Austronesian Culture History: The Window of Language," in *Prehistoric Settlement of the Pacific,* ed. Ward Hunt

might expect to find at least some vestiges of these skills among conservative sailors of the Philippines and Indonesia. Surprisingly, however, although students of Oceanic navigation have long thought that its roots must lie in this region, only recently have they turned their attention to searching for vestiges of traditional navigation in Southeast Asian waters, and so far just in the Indonesian Archipelago. Inquiries made by several researchers during the 1970s indicated that indeed some traditional Indonesian sailors used the stars, winds, and swells in ways similar to those employed in Oceania.[113] During the late 1980s and early 1990s, Gene Ammarell conducted intensive research on the navigation practices of the Bugis, a seafaring people from southern region of Sulawesi (Celebes) Island. His inquiries give us our first systematic look at surviving traditional navigation in that part of the world.[114]

A significant proportion of Indonesia's interisland shipping is still carried by wooden sailing ships that combine design and construction features of both European and local origin. The Bugis, who are particularly noted for their sturdy, ketch-rigged *pinisi,* the largest of the Indonesian sailing vessels, are major participants in this trade. Although during the past twenty years or so the *pinisi* have been motorized, these vessels still depend on their sails when the wind is fair. Furthermore, as Ammarell has pointed out, even though they carry magnetic compasses, most Bugis navigators can still guide their vessels in reference to the stars, winds, and swells. Particularly during the night, they orient themselves and steer by horizon stars, and like their Oceanic cousins they memorize these and specific interisland courses in terms of "star paths." When necessary, they can switch to the swells and winds for orientation and steering, although now a magnetic compass (if working properly) offers an easier alternative.[115] The Bugis navigators conceive of directions in terms of both wind or star compasses, of which Ammarell recorded two examples, one with twelve points, the other with sixteen. As in the Carolines today, even when using a magnetic compass the Bugis refer to directions by the traditional terms for the points of their own compasses. Ammarell's study, along with the previously collected material, therefore seems to confirm some continuity between traditional Indonesian and Oceanic navigation.[116]

If we cast our comparative net wider, it is also apparent from a variety of sources that Arab navigators sailing in the Indian Ocean oriented on and steered by horizon stars and employed a star compass.[117] Although it is possible that this correspondence between Arab and Austronesian navigation is a function of independent, parallel development, given that Southeast Asian waters border on the Indian Ocean as well as the open Pacific, it seems more likely that the similar Arab and Austronesian uses of the stars may be connected. After all, just as the Arab traders were noted for sailing to Southeast Asian and southern Chinese ports, so did Austronesian sailors sail west into the Indian Ocean, as is evinced by the spread of outrigger canoes to South India and Sri Lanka, where they are still used by fishermen, and the Austronesian colonization of Madagascar.

It is curious, however, that the closest correspondences between Arab and Austronesian navigation involve the Carolinian star compass. The Arab and Carolinian star compasses share eighteen points demarcated by the rising and setting points of nine stars. Furthermore both compasses are aligned on rising Altair, not on Orion, which would give true east, or on Polaris, which would give true north.

In this chapter I have presented the Carolinian star

Goodenough (Philadelphia: American Philosophical Society, 1996), 28–35, and Wilhelm G. Solheim, "The Nusantao Hypothesis: The Origin and Spread of Austronesian Speakers," *Asian Perspectives* 26, no. 1 (1984–85): 77–88.

113. While passing through Jakarta in 1972, I learned from the navigators of trading boats anchored in its harbor that they used horizon stars for orientation and steering. Subsequently, David Lewis briefly investigated traditional Indonesian navigational practices (David Lewis, "Navigational Techniques of the Prahu Captains of Indonesia" [unpublished manuscript, 1980]), and Baharuddin Lopa outlined some traditional navigational practices in his dissertation, "Hukum Laut, Pelayaran Dan Perniagaan (Penggalian dari bumi Indonesia sendiri)" (Ph.D. diss., Universitas Diponegoro, Semarang, Indonesia, 1982).

114. Gene Ammarell, "Navigation Practices of the Bugis of South Sulawesi, Indonesia," in *Seafaring in the Contemporary Pacific Islands: Studies in Continuity and Change,* ed. Richard Feinberg (DeKalb: Northern Illinois University Press, 1995), 196–218, a preliminary article drawn from his dissertation research ("Bugis Navigation" [Ph.D. diss., Yale University, 1995]).

115. Ammarell, "Navigation Practices," 209–14.

116. Although Ammarell does not consider the issue of mapping in his article, Gosling, writing about the seamen of Trengganu on the Malay Peninsula, observed that in coastal piloting they relied on "mental" maps of headlands and ports covering the coastline of the entire Gulf of Thailand. L. A. Peter Gosling, "Contemporary Malay Traders in the Gulf of Thailand," in *Economic Exchange and Social Interaction in Southeast Asia: Perspectives from Prehistory, History, and Ethnography,* ed. Karl L. Hutterer (Ann Arbor: Center for South and Southeast Asian Studies, University of Michigan, 1977), 73–95, esp. 85.

117. Gabriel Ferrand, *Le K'ouen-louen et les anciennes navigations interocéaniques dans les Mers du Sud* (Paris: Imprimerie Nationale, 1919); Gerald R. Tibbetts, *Arab Navigation in the Indian Ocean before the Coming of the Portuguese* (London: Royal Asiatic Society of Great Britain and Ireland, 1971); idem, "The Role of Charts in Islamic Navigation in the Indian Ocean," in *The History of Cartography,* ed. J. B. Harley and David Woodward (Chicago: University of Chicago Press, 1987–), vol. 2.1 (1992), 256–62; Joseph von Hammer [Hammer-Purgstall], trans., "Extracts from the Mohit," *Journal of the Asiatic Society of Bengal* 3 (1834): 545–53 and 7 (1838): 767–74; James Prinsep, "Note on the Above Chapter ['Extracts from the Mohit']," *Journal of the Asiatic Society of Bengal* 7 (1838): 774–80; and idem, "Note on the Nautical Instruments of the Arabs," *Journal of the Asiatic Society of Bengal* 5 (1836): 784–94. On Indian navigation in the Indian Ocean and the use of the compass card, see Joseph E. Schwartzberg, "Nautical Maps," in *History of Cartography,* vol. 2.1, 494–503.

compass, as well as *etak* reckoning and other features of the Carolinian navigation system, as elaborations that were developed from a more general Austronesian base to fit navigational requirements in the Caroline Islands chain. As I mentioned previously, the alignment of the Carolinian star compass on Altair seems uniquely adapted to the way the Caroline Islands are spread out along a long, narrow band between 6° and 10° north latitude, because this means that Altair, which rises 8.8° north, passes overhead within no more than a few degrees of all the islands in the chain. If this reasoning is correct, then why would Arab navigators sailing between Indian Ocean ports, many of which are ten degrees or more north of the path of Altair, employ a star compass centered on that star and seemingly adapted to sailing in a latitude much closer to the equator? Surely a compass centered on Polaris, which the Arabs used extensively to measure latitude, would have made more sense for them.

In his detailed study of this issue, Michael Halpern concludes that the most likely explanation is that the Carolinian compass, including its focus on Altair and the star referents for eighteen of its thirty-two points, must have diffused westward from Micronesia to Arab navigators, who adopted it for their own use.[118] Although the tendency among researchers has been to assume that once the islands of Remote Oceania were settled there was little or no contact with the outside world until Europeans began to enter the Pacific, a good case can be made that the people living along the western edge of Micronesia had some communication with the islands to the west of them. As we have seen in the case of Klein's early chart of the Carolines, canoeloads of Caroline Islanders periodically were driven to the Philippines. Furthermore, at the time of first European contact, the people of Belau, the group of islands at the western edge of the Carolines, were using a kind of glass money composed of beads and segments of bracelets that apparently came from the Philippines and may ultimately have had Roman or Chinese origins.[119] If Halpern's thesis is correct, it may be that one of Oceania's exports to the wider world system prevailing before Western Europeans began their maritime expansion was intellectual: a highly sophisticated, albeit instrumentless, way to use the heavens for navigation.

118. Michael Halpern, "Sidereal Compasses: A Case for Carolinian-Arab Links," *Journal of the Polynesian Society* 95 (1986): 441–59.

119. Douglas Osborne, *The Archaeology of the Palau Islands,* Bernice P. Bishop Museum Bulletin, no. 230 (Honolulu: Bishop Museum Press, 1966), 477–94.

APPENDIX 13.1
DOCUMENTED STICK CHARTS IN MUSEUM COLLECTIONS, MADE BEFORE 1940

Institution	Reference	Date Acquired	Dimensions (cm)	Provenance
Amsterdam, Universiteitsbibliotheek	Kaartenzl. 100-03	1900	25 × 55	
	Kaartenzl. 100-03	1900	47 × 50	
Basel, Museum für Völkerkunde	VC 32	1904		Acquired in exchange, Museum für Völkerkunde, Freiburg
	VC 202	1904		Acquired in exchange, Museum für Völkerkunde, Freiburg
Berlin, Museum für Völkerkunde	VI 24670	1905	167 × 123	
	VI 14669	1897	87 × 48	
	VI 24668	1905	77 × 54	
	VI 15281	1898	102 × 56	
	VI 15282	1898		
	VI 15283	1898		
	VI 5802	1883	105 × 36	
	VI 24667	1905	99 × 90	
	VI 24673	1905	91 × 91	
	VI 50452	1939	44 × 28	
	VI 8309	by 1898	38 × 36	
	VI 50453	1939	42 × 26	

APPENDIX 13.1 (*continued*)

Institution	Reference	Date Acquired	Dimensions (cm)	Provenance
Berne, Bernisches Historiches Museum, Ethnography Department	Mikr. 32	1920	55 × 86	Museum für Völkerkunde, Hamburg, before 1920
	Mikr. 33	1920	43 × 90	
Burgdorf, Switzerland, Museum für Völkerkunde	Nr. 04676	1936	43 × ?	Collected by Dr. Kordt
Cambridge, Mass., Peabody Museum of Archaeology and Ethnology, Harvard University	00-8-70/55584	1900	95 × 101	Collected by Agassiz and Woodworth, *Albatross* expedition, 1899–1900
	00-8-70/55587	1900	81.5 × 67.5	Collected by Agassiz and Woodworth, *Albatross* expedition, 1899–1900
Chicago, Field Museum of Natural History[1]	FM #38298 (acc. 1969)	1900	106.5 × 84	Collected by Alexander Agassiz and W. McM. Woodworth during U.S. Fish Commission *Albatross* expedition, 1899–1900. Acquired by exchange from Peabody Museum, Cambridge, 1932.
Cologne, Rautenstrauch-Joest Museum, Museum für Völkerkunde	43336	1902–4	42 × 26	An employee of a German company, Jaluit Gesellschaft, was active in the Ralik Group of the Marshall Islands in 1902–4. Both charts were later acquired by the museum from the employee in 1952.
	43337	1902–4	44 × 27.5	
Dresden, Staatliches Museum für Völkerkunde	Kat. Nr. 42524	1928	44 × 28	
Göttingen, Institut und Sammlung für Völkerkunde, Universität Göttingen	Stabkarte Sign. OZ 462	1930	44 × 27.5	Collected by Adolf Rittscher
	Stabkarte Sign. OZ 463	1930	41.5 × 25.5	Collected by Adolf Rittscher
Hamburg, Museum für Völkerkunde	E 977	1885		
	E 978	1885		
	E 1864	by 1900		Godeffroy Collection. In the second half of the nineteenth century, the Godeffroy family owned a trading company in Hamburg specializing in ethnographic objects from the South Pacific and Australia; the family also collected and had its own museum. At the end of the nineteenth century, the Godeffroy Collection was acquired by the Hamburg Museum für Völkerkunde, which had been one of its customers.
	E 1865	by 1900		Godeffroy Collection
	E 1866	by 1900		Godeffroy Collection
	E 1867	by 1900		Godeffroy Collection
	391:10	1910		
	392:10	1910		
	393:10	1910		
	394:10	1910		

APPENDIX 13.1 (*continued*)

Institution	Reference	Date Acquired	Dimensions (cm)	Provenance
(*cont.*) Hamburg, Museum für Völkerkunde	395:10 396:10	1910 1910		
Honolulu, Bernice P. Bishop Museum	Original cat. no. 3481; current acc. no. 1892.011	1892	96 × 61.5	Gift of Rev. C. M. Hyde, Hawaiian Board of Missions. May have been collected by Hawaiian missionaries serving in the Marshall Islands, who sent or brought it back to Hawai'i. Appears to be a *meddo*.
	Original cat. no. 6806(A); current acc. no. 1892.005	17 December 1892	112 × 50	Gift of Hawaiian Board of Missions. Listed in catalog as "chart Mede." Appears to be a *meddo*.
	Original cat. no. 6808(B); current acc. no. 1892.005 [same as above]	17 December 1892	99 × 71	Gift of Hawaiian Board of Missions. Listed in catalog as "chart Mede." Appears to be a *meddo*.
London, British Museum, Department of Ethnography[2]	Navigational Chart 1904.6-21.34	1904	100 × ?	
Munich, Staatliches Museum für Völkerkunde[3]	Inv. Nr. 91.835 Inv. Nr. 08.583 Inv. Nr. 08.584	1891 1908 1908	107 × 59 100 × 24.5 100 × 49	W. Schubert Wolfgang Dröber Wolfgang Dröber
New York, American Museum of Natural History[4]	80.0-3317	1914	95 × 93	One of two charts commissioned for and purchased by Robert Louis Stevenson in June 1890 (see below, University Museum, Philadelphia, for the second chart). After Stevenson's death, the chart was on concession to the Edinburgh Museum in 1901. Purchased in 1914 for the American Museum of Natural History by Robert Lowie for $80 (auctioned with Stevenson's "curios," New York). Restored in 1965 and again ca. 1979.
Oxford, England, Pitt Rivers Museum, School of Anthropology and Museum of Ethnography[5]	1897.1.2	1897	53 × ?	Dr. Irmer, governor of the Marshall Islands, obtained it from Chief Nelu, Jaluit, 1896. Graham Balfour, who traveled in the Pacific in the 1880s and 1890s, presented it to the museum. (Graham Balfour may have been a cousin of Henry Balfour, the museum's first curator.)
Paris, Musée de l'Homme	MH.31.33.24	1931	43 × 27.5	
Philadelphia, University Museum, University of Pennsylvania[6]	P 3297	1914	124.5 × 73.5	Robert Louis Stevenson (see American Museum of Natural History entry, above)

APPENDIX 13.1 (*continued*)

Institution	Reference	Date Acquired	Dimensions (cm)	Provenance
Salem, Mass., Peabody Essex Museum	E. 12210	1900	75 × 75	Collected by Alexander Agassiz and W. McM. Woodworth during U.S. Fish Commission *Albatross* expedition, 1899–1900. From Peabody Museum of Archaeology and Ethnology, Harvard University, Cambridge, Mass.
Sydney, Australian Museum	E.5513	by 1872	97 × 84	
	E.15861	1906	112 × 86	Donated by P. G. Black
Vienna, Museum für Völkerkunde	Inv. no. 25.735	1887	124 × 76	Museum für Völkerkunde, Hamburg
	Inv. no. 123.604	by 1903	44 × 28	Adolf Rittscher
	Inv. no. 123.605	by 1903	42 × 26	Adolf Rittscher
Washington, D.C., Smithsonian Institution, National Museum of Natural History, Department of Anthropology	E 206186	1900		All four charts donated by Charles H. Townsend and H. F. Moore
	E 206187	1900		
	E 206188	1900		
	E 206189	1900		

Note: This appendix was prepared from a survey of fifty-eight institutions thought to hold stick charts, and therefore is not a complete list. Publications that illustrate and discuss several of these charts include Captain [Otto?] Winkler, "On Sea Charts Formerly Used in the Marshall Islands, with Notices on the Navigation of These Islanders in General," *Annual Report of the Board of Regents of the Smithsonian Institution, 1899,* 2 vols. (Washington, D.C.: United States Government Printing Office, 1901), 1:487–508 (a translation of "Ueber die in früheren Zeiten in den Marschall-Inseln gebrauchten Seekarten, mit einigen Notizen über die Seefahrt der Marschall-Insulaner im Allgemeinen," *Marine-Rundschau* 10 [1898]: 1418–39, but with more illustrations); A. Schück, *Die Stabkarten der Marshall-Insulaner* (Hamburg, 1902); Bruno F. Adler, "Karty pervobytnykh narodov" (Maps of primitive peoples), *Izvestiya Imperatorskago Obshchestva Lyubiteley Yestestvoznanya, Antropologii i Etnografii: Trudy Geograficheskago Otdeliniya* (Proceedings of the Imperial Society of the Devotees of National Sciences, Anthropology, and Ethnography: Transactions of the Division of Geography) 119, no. 2 (1910), 198–217; and Augustin Krämer and Hans Nevermann, *Ralik-Ratak (Marshall Inseln)* (Hamburg: Friederichsen, De Gruyter, 1938), 221–30.

[1] Ralph Linton and Paul S. Wingert, *Arts of the South Seas* (New York: Museum of Modern Art, 1946), 67.

[2] T. A. Joyce, "Note on a Native Chart from the Marshall Islands in the British Museum," *Man* 8 (1908): 146–49, fig. 1.

[3] Rose Schubert, Ernst Feist, and Caroline Zelz, "Zur frühen Seefahrt in der Südsee: Schiffahrt und Navigation in Polynesien und Mikronesien," in *Kolumbus: Oder Wer entdeckte Amerika?*, ed. Wolfgang Stein (Munich: Hirmer, 1992), 90–99, and Wolfgang Dröber, *Kartographie bei den Naturvölkern* (1903; reprinted Amsterdam: Meridian, 1964), 56.

[4] Fanny Stevenson, *The Cruise of the "Janet Nicol" among the South Sea Islands* (New York: C. Scribner's Sons, 1914), 150–51 and 159–60.

[5] H. Lyons, "The Sailing Charts of the Marshall Islanders: A Paper Read at the Afternoon Meeting of the Society, 14 May 1928," *Geographical Journal* 72 (1928): 325–28; this item is referenced as 18″ × 11″.

[6] Henry Usher Hull, "A Marshall Islands Chart Presented to the Museum by the Honorable John Wanamaker," *Museum Journal* 10 (1919): 35–42, fig. 15.