

THE ORIGINS OF THE CAROLINIAN SIDEREAL COMPASS

A Thesis

by

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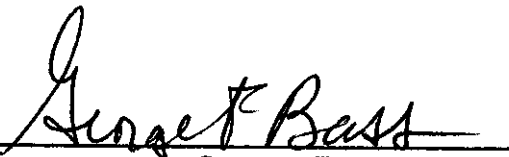
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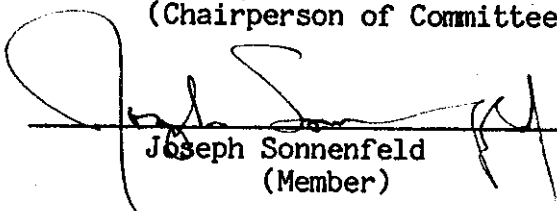
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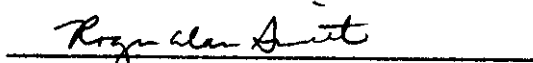
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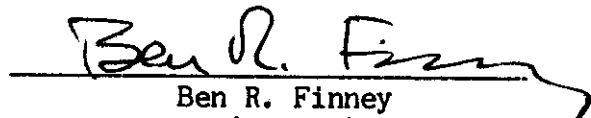
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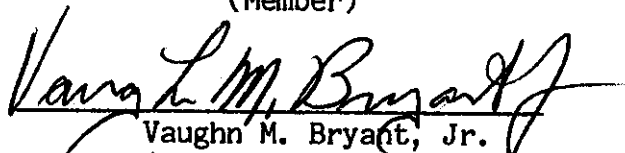
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ABSTRACT

The Origins of the Carolinian Sidereal Compass. (May 1985)

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The sidereal compass of the Caroline Islanders is a conceptual tool that organizes navigational knowledge and permits long-distance voyaging and accurate landfalls without the use of instrumentation. Remnants and hints of similar systems are reported all across the Pacific while descriptions and representations of a similar compass are extant in old Arab nautical texts. These resemblances have alternately been ascribed to independent invention and diffusion.

Tropical sidereal navigation in general is examined and the current state of knowledge of the various compasses described. A theoretical framework for the evaluation of diffusionist versus inventionist arguments is developed and a set of criteria is presented. The Carolinian and Arab compasses are analyzed from a temporo-astronomical standpoint in an attempt to reveal any past conjunctions. We will give these data a cultural context by tracing the broad movements of peoples in the Indo-Pacific region and comparing cultural similarities, differences, and possibilities of contact. It is concluded that Arab navigation was probably influenced by that of Austronesian seafarers in the Indian Ocean, though not directly by Carolinians, after the former had begun to elaborate an incipient sidereal compass. The underlying unity of Oceanic navigational traditions is also affirmed.

DEDICATION

A half century ago, an elderly sailor of Celebes lamented,
"Soon we shall be gone too, and even the memories will be forgotten"
(Collins 1936:140). This thesis is dedicated to the preservation of
those memories.

ACKNOWLEDGMENTS

I would like to thank Dr. Edwin Doran, Professor Emeritus of Geography at Texas A&M, for his early help and guidance. It was he who planted the seed that grew into this project. My Committee, for their encouragement, aid, and patience, are also deserving of thanks. Dr. Burton Jones and graduate student, Steve Allen from the University of California, Santa Cruz Astronomy Department gave generously of their time to supply mathematical formulas and explain astronomical concepts. Many others, too numerous to mention, offered useful bits of information and valuable leads all along the way. Finally, I want to express my special appreciation to friends Claudia and Akram, also of Santa Cruz, whose translations of primary source material from German and Arabic facilitated the work immeasurably.

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CHAPTER I

INTRODUCTION

When European seafarers first came upon the islands of the northwest Pacific in the sixteenth century, they missed entirely the low coral atolls of the Carolines. This chain stretches east and west between three and ten degrees north latitude and covers over 30 degrees of longitude (Fig. 1). Peopled perhaps millennia before the first Europeans entered the region, the Carolines remained virtually untouched by Western influence until the nineteenth century (D. Lewis 1978a:46; Alkire 1977:3). Their small size, isolation, and relative lack of natural resources made them unattractive targets for European colonization, exploitation, or the establishment of way stations. All of Micronesia, one of the three great groupings, along with Melanesia and Polynesia, of the Pacific islands, contains only 2000 km² of land area. This is divided among some 2500 islands of the Carolines, Marianas, Marshalls, Gilberts (now Kiribati), and assorted smaller groups (Bellwood 1979a:104-105).

The story of how these tiny specks of land lost in an immense ocean were first discovered and populated by seafaring peoples of Asian origin at a time when Western voyaging remained almost entirely within the confines of the Mediterranean may forever remain mystery. But we are indeed fortunate that research of the last 30 years has revealed the continued practice of at least some of the navigational

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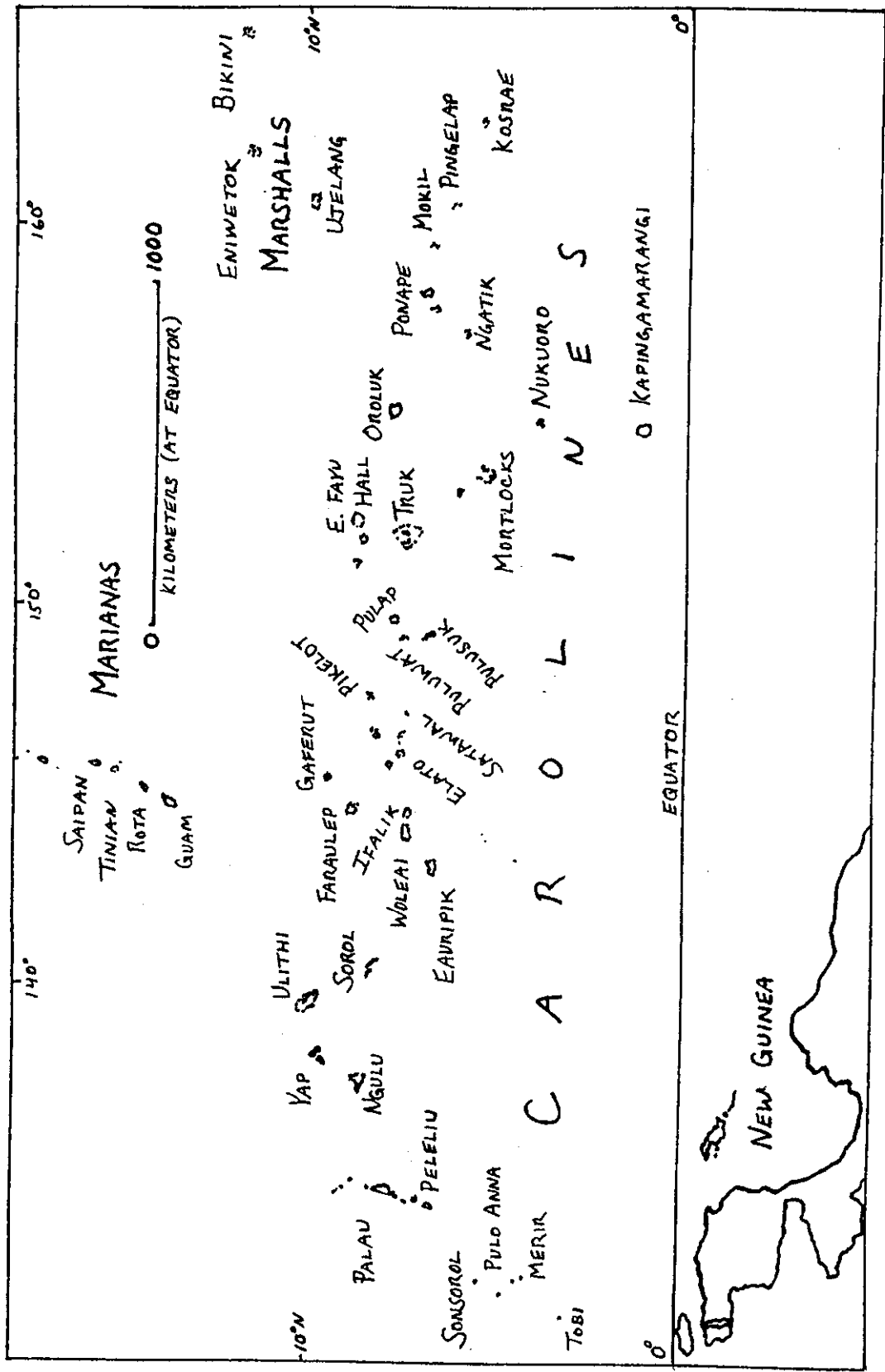


Figure 1. The Carolines and adjacent islands (after Gladwin 1970).

techniques of these people. Though quickly being replaced by the magnetic compass, enough of the non-instrumental system of the Carolinians has persisted to our day to allow us to explain its use as practiced in the middle decades of the twentieth century. In this paper, we will examine one part of this system, the sidereal, or star, compass as known on several atolls of the central Carolines. Its structure and use will be briefly explained in the context of Carolinian navigation in general. Our major focus, however, will be the possible origins of this construct. Was it developed locally, relatively free from outside influence? Was it brought, already refined, from the original or an intermediate homeland of these Micronesian seafarers? Or can links be demonstrated between the Carolinian compass and other, similar, constructs reported from Arabia, Indonesia, and other parts of the Pacific? Finally, how much of specific navigational practices can be attributed to a generalized human response to problems of wayfinding?

It is common for a society to develop a theory of geographic orientation, one which locates it in relation to its neighbors, real or imagined. The imperial Chinese were the Middle Kingdom, the center of the world. And the Polynesian name for Easter Island, Te-Pito-o-te-Henua, means "The Navel of the World" (Heyerdahl 1980:291). On a more practical side, individuals must be able to find their way through a particular environment, be it to a favorite fishing hole in the ice, the corner bakery, or another island hundreds of kilometers away. Researchers have sought universal principles of human spatial orientation both by experimentation and observation. As might be expected, blindfolded subjects, when spun about, generally

showed poor geographic orientation, though individuals varied widely in ability (Witkin 1946:153). It has been said that when given a choice or faced with an obstacle in his or her direct path, a person will usually turn to the right (Gatty 1958:58). Gatty attributes this tendency to a universal bias toward the right reflected in our moral and legal terminology. Howard and Templeton (1966:257-258) noted that humans and animals tend to veer right when lost or sensorily deprived. This removes the bias of a values-based explanation. They speculated that this might be caused by a "fundamental circling mechanism" or body asymmetry. Gatty (1958:59) also mentioned such things as leg length and arm strength differences leading to deviation from a straight line. While interesting, the evidence does not permit any definitive conclusions pertinent to the study of non-instrumental navigation.

Experiments designed to differentiate geographical knowledge derived from examining a map from that learned by actually navigating a field have similarly failed to reveal sharp delineations. For instance, despite some initial variation, it was found that increased experimental knowledge could improve map knowledge (Thorndyke and Hayes-Roth 1982:564, 581). This is supported by the fact that reasonably accurate maps were made before the advent of sophisticated land-based instrumentation or satellite photos allowed today's precision. Before the arrival of Europeans, the Eskimaux of southeast Greenland were known to carve wooden representations of the coast and nearby islands to describe regions unfamiliar to others (Sølver 1957:188).

Other experiments have aimed at separating the geocentric

elements of orientation systems, those focusing on direction rather than place (Sonnenfeld 1982:70-71), into two different types of subsystems. The first requires some objective, standardized mechanism (such as a magnetic compass) enabling the user to navigate between any two points with "self" at the center of the field. It was thought to be common only to "civilized" (read: "technologically advanced") peoples. The second requires no instrumentation but necessitates constant reference to a starting point. It is thus, a dead reckoning system and supposedly typical of animals and "primitive" (read: "technologically simple") humans. While both approaches to wayfinding are, indeed, commonly used, it cannot be concluded that either is innate to a certain people or culture. Experiments in Geneva found both systems used by highly "civilized" individuals (Howard and Templeton 1966:262-263).

As Gatty maintained (1958:passim), there is no mysterious, innate sense of direction which guides technologically simpler people over trackless wastes of desert, water, or ice, or through impenetrable forest. The !Kung of southern Africa become lost in a heavy mist and Saharan Arabs travel single file at least in part so that those in the rear can warn the leaders should they veer off the track (Howard and Templeton 1966:265). Instead, they are careful observers of natural phenomena such as terrain, the tracks of animals and flight paths of birds, clouds, wave patterns, and celestial bodies. In addition to form, they often note color, sound, and odor as clues to their desired course. These same signs have been and are used by "modern" navigators as well (Gatty 1958:75-76, 170). How often have we found that corner bakery, after all, by following our

noses? On the purely cognitive level we can at this point do little better than to conclude along with Howard and Templeton (1966:271), that orientation skills are "very complex and very idiosyncractic."

This conforms closely to Thomas Gladwin's (1970:203) description of navigation on Puluwat, a central Carolinian atoll where indigenous methods of seafaring are in use to this day. The navigational precepts form a complete cognitive system including a body of theory and attendant techniques. The theory expresses an ideal which is modified in practice through varying application of the techniques. It is clearly a dead reckoning system, but one which includes a (relatively) standardized mechanism, the march of the stars across the vault of the heavens. But the Carolinian navigators are only one of numerous seafaring peoples whose maritime technology and traditions share common threads stretched across 18,000 km of the earth's surface, from the east coast of Africa to the eastern Pacific Ocean. This vast Indo-Pacific region (Fig. 2) served as a stage for some of the most intrepid voyagers ever to make sail. And despite the great cultural diversity of these people, they shared, as we shall see, certain nautical traits not found along the world's other great sea lanes.

Sailing conditions in the Pacific vary, of course, from one part of the ocean to another and from one season to the next. One could expect no less of a body of water covering over 166,000,000 km², more than the total land area of our planet (Espenshade 1982:242). Unlike the Atlantic, the Pacific offers generally good sailing born of relatively regular and steady currents and tradewinds. Even during the stormy season the sky is rarely obscured for more than three days

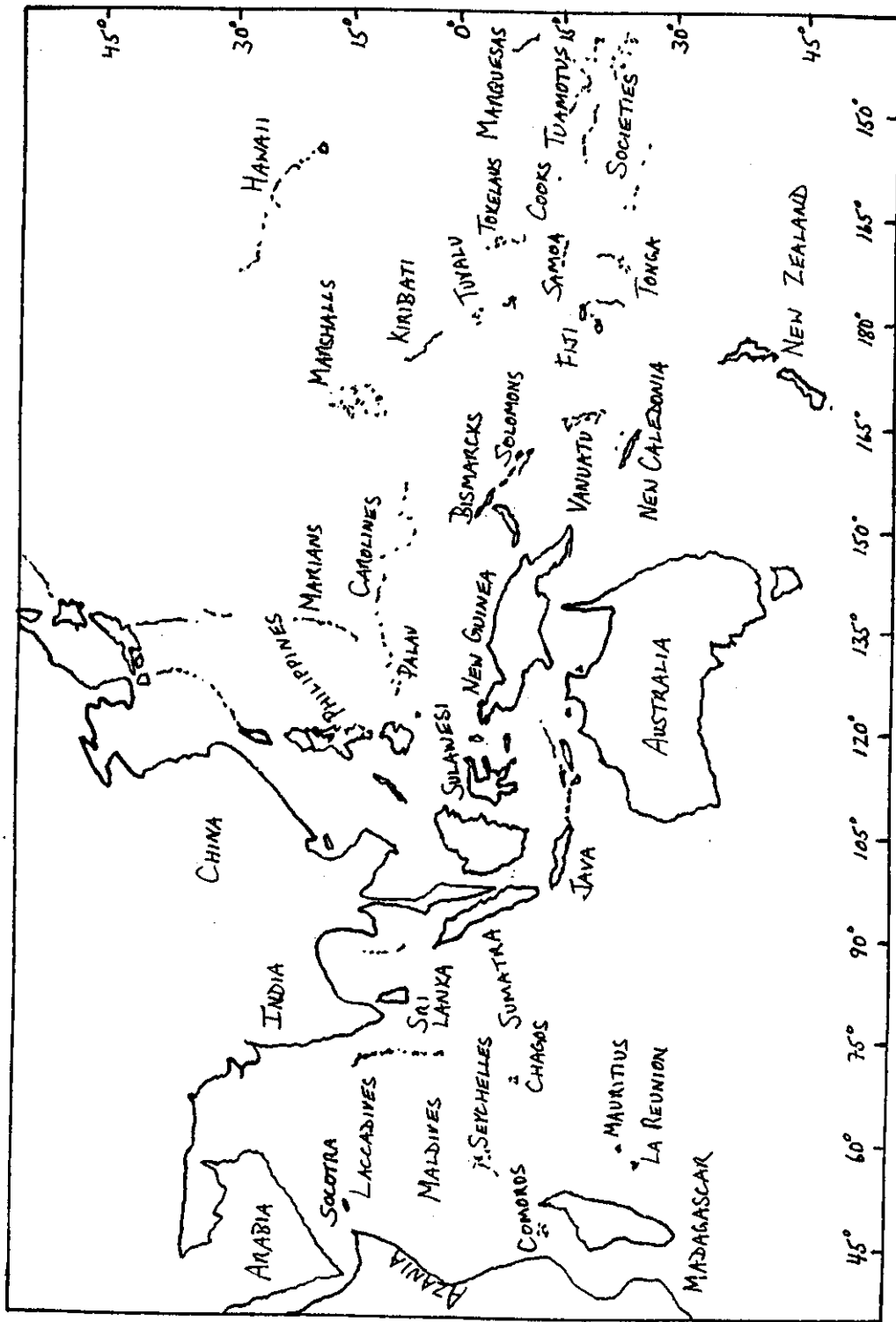


Figure 2. The Indo-Pacific region (after Doran 1981).

at a time in some regions (Lewthwaite 1967:64; Dodd 1972:32). In the central Carolines, for example, the period from January through March is characterized by very strong northeast tradewinds and heavy surf and there is little or no sailing. The voyaging season opens in April as the trades moderate and continues through a summer (northern hemisphere) of variable winds. As the doldrum belt moves north of the region around July or August, the trades move into the southwest. The doldrums move south again in September bringing on the typhoon season. As the east and northeast trades increase in force between October and December, the weather patterns stabilize once again culminating in the mid-winter end to the period of regular voyaging (Gladwin 1970:40-41, 43-44).

While weather patterns are quite different in the Indian Ocean, here, too, a regular sequence obtains. Seafaring in the region is dominated by the alternating winds known as the monsoon. During the winter months a vast high pressure system sits over the Asian mainland causing northeast winds from the Philippine Sea to the African coast, except through Indonesia where the predominant winds are out of the northwest. As the high is replaced by a low in the summer months, the winds reverse and blow from the southwest (southeast in Indonesia). This period of southwesterlies was traditionally one of little or no voyaging among Arab sailors making the run to India (Grosset-Grange 1972b:245). The discovery of this pattern of alternation is attributed to the legendary pilot Hippalus sometime in the first century A.D. (Mookerji 1962:86). It may, however, merely be the first time such voyaging secrets were revealed to or recorded by Europeans.

Beyond the physical and meteorological background, the Indo-Pacific region is unified by certain traditions of sailing technique and vessel construction. Jett (1978:604) cites the islands of Indonesia and the adjacent Asian mainland as the homeland of the oldest complex of nautical traits known. These include the sailing raft, the outrigger, and particular navigational procedures which presumably reached the southwest Pacific by about 1500 B.C. While sewn or lashed boats are known from all across the Old World and perhaps beyond (Doran 1971:123; Paris 1955:66), the more limited distribution of particular types of watercraft lend credence to Jett's contention. In the last century it was noted that the construction details of rattan-lashed rafts of New Guinea were exactly like those found in Madras, on the Ganges, in Manila, and on other Asian islands (Fox 1875:426). And the Indian subcontinent is seen by Bowen (1956:286) as a diffusion source for such traits as hull stitching, sail and mast types, hull shape, mat cabins, and steering oars. In his scenario, these features originated in the Indus Valley as early as 2500 B.C. rather than in Egypt, as is often thought. The outrigger, one of the most characteristic features of Indo-Pacific craft, is seen as part of a single cultural tradition beginning several thousand years ago in Southeast Asia. The single outrigger, ubiquitous in Oceania (Bellwood 1979a:297) is found from the Tuamotus in the east to Madagascar in the west (Doran 1971:Fig. 41). Hornell (1934:319, 329) noted affinities between canoes of East Africa and Indonesia and pointed to architectural similarities between the great ninth-century Javanese stone ruins at Boro Budur (carrying seafaring motifs) and those in Zimbabwe of a slightly later date. Further

parallels include seafaring words common to Madagascar, the Philippines, Polynesia, and, possibly, Taiwan. These terms date to the dawn of the Austroneasian prototype language around 3000 B.C. and include those for outrigger float and beams, sail, steering paddle, and canoe rollers (D. Lewis 1978b:98).

Of course, the Indonesian origin of Madagascar's inhabitants is now well known. Only the timing, exact point of origin, and the route are in question. The twelfth-century Arab geographer, Idrisi, mentioned that the Indonesian merchants in East Africa and their local trading partners could understand each other's language (Tibbetts 1957:23; Mookerji 1962:135), though some (Di Meglio 1970:114) question his accuracy. And a thirteenth-century Arab observer, Idn Sa'id, called the people of Madagascar "les frères des Chinois" (Ferrand 1918:121). The westward migrations from Indonesia have been attributed to Hinduized Javanese of around A.D. 130 (Ferrand 1918:112) and seafarers of Borneo at about the time of Christ (Jett 1971:15), though Ferrand earlier (1910:passim) discussed a Sumatran origin and later time period for these peregrinations. We will have occasion to return to these Austronesian people (formerly called Malayo-Polynesians) in a subsequent chapter.

The Indo-Pacific seafaring tradition did not develop in isolation from that of the Chinese, though the latter eventually took a different course and will remain peripheral to our investigation. Certainly by the fifth century B.C. and perhaps as long as two millennia earlier, the Chinese had seagoing rafts, probably similar to those of their Asian neighbors. In fact, the ancient inhabitants of southeastern China were known as Pai-Yueh, "the navigators" and East

Asia today contains the greatest variety of watercraft in the world (Jett 1971:10-11). The essential point, however, is the relative uniformity of the nautical traditions covering areas of the globe thousands of kilometers apart. But the warm seas, regular winds, and light, beachable craft were not the only elements contributing to this picture. The night sky was a key factor in forming the navigational systems of these peoples and in differentiating them from the wayfinding methods of their counterparts in higher latitudes. In the next chapter we will explore the unique features of that sky and those methods peculiar to the Indo-Pacific region.

CHAPTER II

NON-INSTRUMENTAL SIDEREAL NAVIGATION

The earth's equatorial regions, bounded by the Tropic of Cancer (23.5°N latitude) and the Tropic of Capricorn (23.5°S latitude), are home to a number of cultures whose indigenous astronomies were every bit as sophisticated as those of more familiar temperate zone civilizations such as the Chinese, Mesopotamian, Egyptian, and Greek. All societies, from earliest times, looked to the sky for guidance in matters practical as well as mystical. But they did not all see the same things. To illustrate, we shall imagine the sky as an inverted bowl whose rim joins the earth at the horizon. This conception is, in fact, common to many indigenous cosmologies (Needham 1959:210, 212; Da Silva and Johnson 1982:Fig. 4). We will project the earth's coordinate system of latitude and longitude onto this dome (Fig. 3). To an equatorial observer, then, the earth's poles will appear at the horizon while lines of latitude will climb straight up, pass overhead and descend straight down on the dome's opposite side. The earth's motion is reflected in that of the sky as the stars rise vertically from the eastern horizon and pass overhead to descend vertically in the west. Celestial motion in the sky's northern half is exactly like that to the south. In such a situation the horizon and the zenith, the point directly overhead, become the most important referents to the observer who seems to be at the very center of the system.

Beyond the tropics, the sky behaves quite differently. Rising

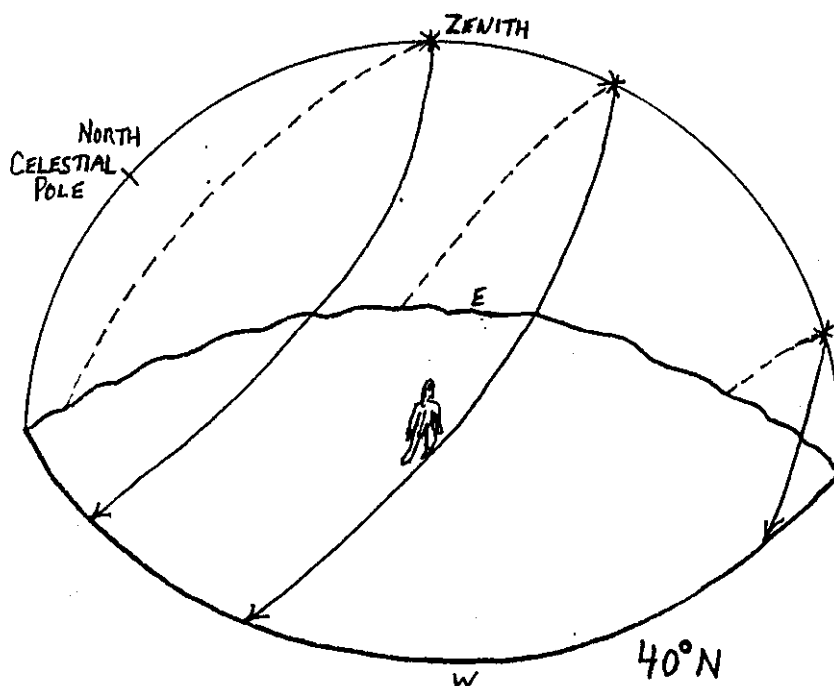
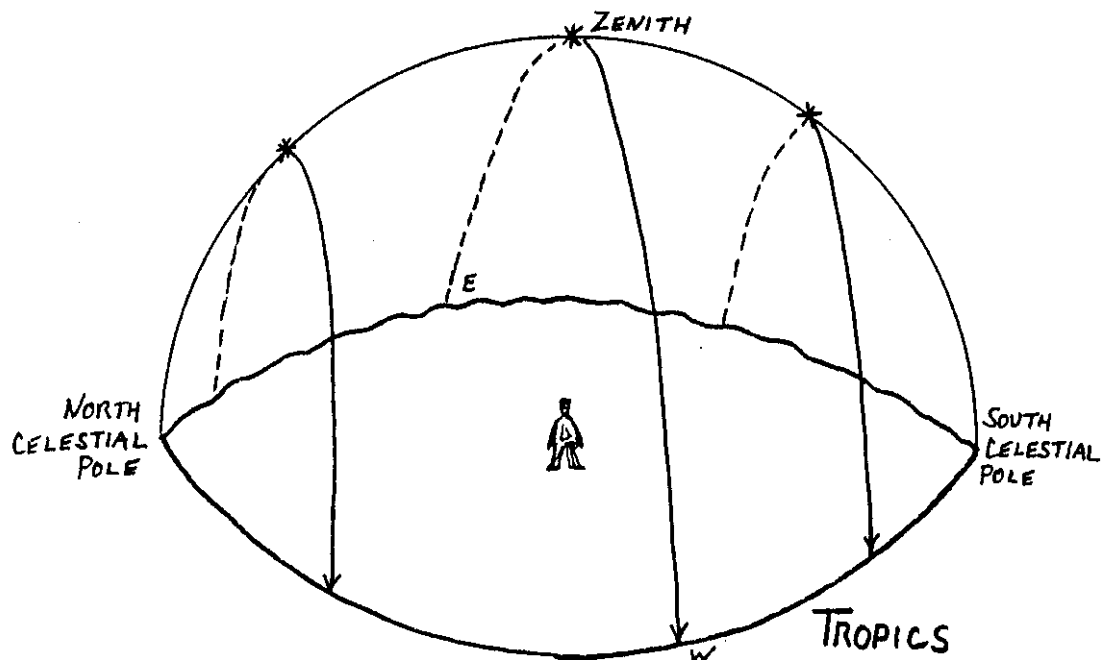


Figure 3. Comparing the movement of the sky in tropic and temperate regions. To the tropical observer, the stars appear to rise and set vertically, passing "up and over." In higher latitudes, the stars rise and set obliquely, describing a circle around the celestial pole (after Aveni 1981).

and setting objects have a strong oblique component to their motion which becomes more pronounced the higher the latitude of the observer. The sky loses its symmetrical quality and objects appear to rotate about a point in the sky determined by projecting the earth's axis onto our dome. Called the celestial pole, this position today is occupied by Polaris in the north but appears empty in the southern sky. As one moves away from the equator, circumpolar stars do not rise and set at all but can be seen to trace a circle around the unmoving celestial pole. In the higher middle latitudes, the significant points of reference are the celestial pole and equator (a projection of the terrestrial equator on our sky dome) and the ecliptic, the path taken by the sun, moon, and planets through the sky. It is along this line that one finds the constellations of our zodiac. The temperate zone is also characterized by a much more pronounced seasonal movement of sun and moon along the horizon than the tropics (Aveni 1981:161).

The indigenous astronomical practices of many different cultures reflect these facts. Chinese astronomy was essentially polar and equatorial in nature and showed little interest in the zenith (Needham 1959:172, 375). Among Oceanic seafarers, Javanese, the Maya, and the Inca, tropical peoples all, the horizon and zenith form the bases for astronomical observation (Aveni 1981:162-169). Naturally, exceptions to this general pattern occur. Pannekoek (1961:50) cites the importance of the horizon to fifth century B.C. Babylonian astronomers who compared the simultaneous rising and setting of different stars. And Aveni (1981:171) notes that Stonehenge in Bronze Age Britain was oriented to the horizon. On the other hand, on

Sonsorol in the Carolines and in Kribati, astronomers used solar movement along the horizon for calendrical purposes (Johnson and Mahelona 1975:23; Goodenough 1953:28). Carolinian navigators sometimes even used the height of Polaris above the horizon to determine latitude as did Roman, Indian, Chinese, and Arab navigators in the temperate zone (D. Lewis 1978b:142-143).

The tropics, then, provide a unique setting for the development of a particular orientation of human to nature. For the seafaring societies of the Pacific Ocean islands, the sky's apparent motion required a particular set of adaptations and rewarded a specific application of human intelligence to natural phenomena. The navigational system used by these people required ingenuity and patience to develop. It is only recently the Western scholars have come to appreciate both the intellectual abstraction, practical efficiency, and consummate skill required of its practitioners. What, then, are the essential elements of this system and how are they applied aboard a small outrigger canoe amid the long swells of the Pacific?

Long before the advent of the magnetic compass and accurate chronometry, sailors around the world found their way across the sea by using, among other natural signs, the stars (Taylor 1957:passim; Conklin 1976). Unlike the sun, moon, or planets, the Declination (celestial latitude) of the stars remains constant over long periods of time. Their rising and setting azimuths, or bearings, do not change, then, over the course of the year (Thomas 1982:2). Nowhere more than among the island societies of the Pacific was this fact turned to the advantage of a seafaring people. And nowhere today do

we find the techniques of non-instrumental star navigation as refined and systematized as on the coral atolls of the central Carolines. The heart of this system is the sidereal compass (Fig. 4).

In this construct, azimuths are determined by the rising and setting points of stars or constellations rather than being determined by the earth's magnetic field as in the more familiar European compass. In its traditional form this Carolinian compass includes 32 points (though Åkerblom 1968:104 found between 28 and 36 depending on locale), as does the traditional compass rose of European mariners. Points in the eastern half of the compass are determined by the rising azimuths of the stars while the western bearings are denoted by the setting azimuths. Thus, with the exceptions of Polaris which indicates north only and the Southern Cross which is used in five different positions in the south, each star represents two directions.

The most important azimuth of the sidereal rose is Altair in the constellation we call Aquila, the Eagle. In the Carolines it is called the Big Bird and determines the east-west line, the main axis of the system (Gladwin 1970:154; Goodenough 1953:5; Thomas 1982:2; Alkire 1970:44). Goodenough (1953:12, 12n.1) notes some confusion over the origin of the name of this constellation, määnap, which, according to him derives from a root meaning "main" rather than being identified with maan, "the bird". However, all subsequent researchers have used the avian denotation. It must also be emphasized that the compass is purely an intellectual abstraction and not a physical object. It exists in the navigator's head rather than being bolted to his vessel. Its only concrete representation is in the form of stones or shells laid out in a circle or square as a pedagogic device for neophyte

Setting

Rising

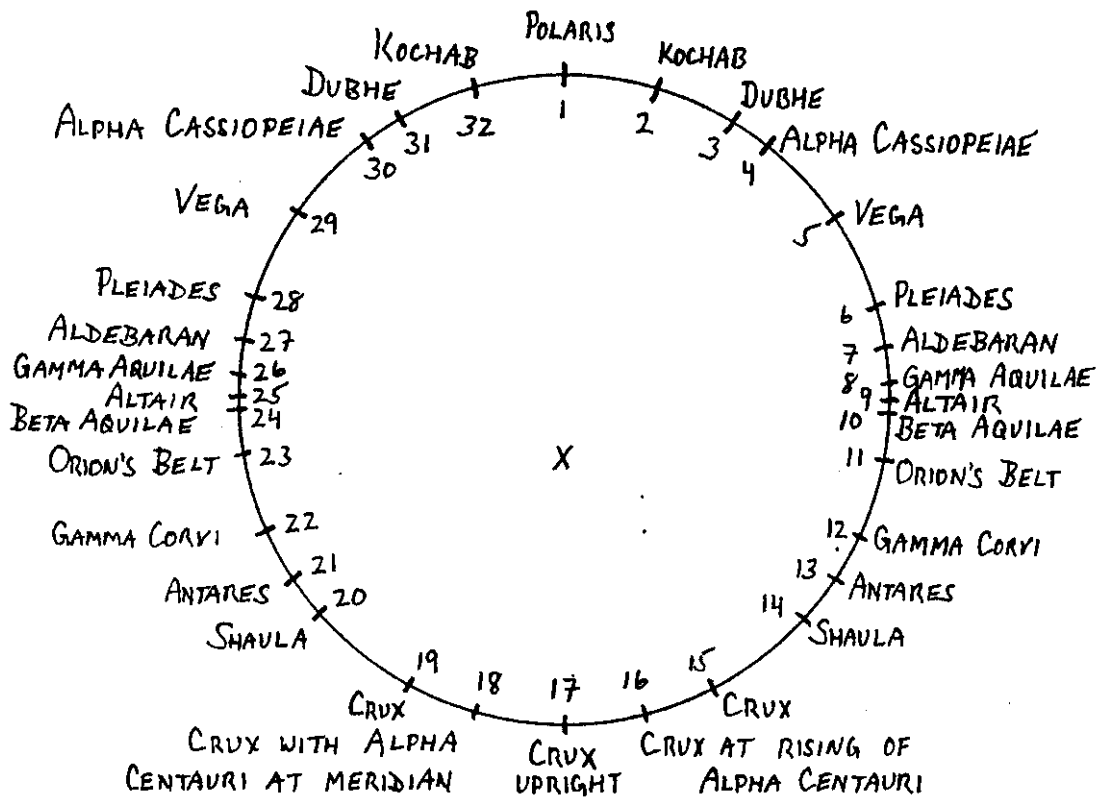


Figure 4. The Carolinian sidereal compass (after Goodenough 1953). The "X" marks the actual astronomical center of the azimuths.

navigators (Gladwin 1970:30; Thomas 1982:3; Alkire 1970:41).

Despite the irregular intervals between the azimuths, the compass is quite symmetrical, the rising point of one star usually being about 180° from the setting point of another (Gladwin 1970:160). The bearings of islands to be visited are given with respect to the compass points (Goodenough 1953:7; Thomas 1982:3). It will be noted that some azimuths are designated by constellation rather than individual star names. Seeking to refine bearing identifications, Gladwin (1970:150) assumed Kochab, the brightest star in Ursa Minor, to be the essential point. Goodenough chose Dubhe to represent Ursa Major and Schedir for Cassiopeia in the face of conflicting published reports, but Gladwin's own informants were unsure and contradictory (Gladwin 1970:150). Actual Carolinian practice is probably best embodied in a phrase used by Mark Twain to describe the navigation of Mississippi River boat pilots. On north-south voyages the Puluwat navigator steers by the "shape of the sky" rather than individual points of light (Gladwin 1970:152).

It can also be seen from Figure 4 that a majority of the compass points are bunched near the east-west line. The compass need not afford greater accuracy than that required to meet the practical needs of its users. Since the Carolines are stretched out in a long east-west chain and most voyages are between islands within that string, it is logical to conclude, with Gladwin (1970:152, 154), that the greater local requirement for east-west accuracy dictated this arrangement. However, David Lewis (1972:67) disputes this claim, citing traditional Carolinian voyages to Saipan in the Marianas as a long distance (over 800 km) north-south trip necessitating great

accuracy. His contention is that in grouping azimuths around the east-west line, the Carolinians were merely taking advantage of convenient stars that lay along that axis. Though Lewis is absolutely correct to note the Saipan voyage as well as the correct star course given by Beiong, a ppalu (navigator) from Pulusuk, to Kapingamarangi, a Polynesian outlier 750 km to the south, his argument flies in the face of tradition and early European reports from the area. Clearly, most voyaging was among the many islands scattered along the Carolinian corridor. Differentiating these many targets requires more azimuths. That is not to say that any given landfall to the east or west requires more accuracy than one to the north or south. In fact, since large changes in latitude adversely affect the accuracy of star courses (Åkerblom 1968:107-108), one might expect more, not fewer north-south azimuths. The fact that this is not the case attests to the compass' sufficiency for what north-south voyaging occurred as well as the greater frequency of east-west trips. The advantage seized by the Carolinians was the system itself, made practicable by their tropical location.

The practicality of this system is also demonstrated by its choice of stars. Many very bright ones such as Rigel and Sirius are ignored completely. Instead, it is so devised that several are visible at any given time throughout the nights of the voyaging season (Goodenough 1953:3; Åkerblom 1968:105-106). Further, since the stars rise about four minutes earlier each evening, the sky changes in appearance as the weeks and months of the voyaging season progress. Too, as a star rises higher in the sky, it becomes less useful as a directional indicator and another must be chosen to replace it. On

Puluwat, stars of the same Declination, or rising point, are said to "travel the same road" (Gladwin 1970:148). These substitute stars are used to hold or set course when the "type star" of the compass is invisible or too high to be used (D. Lewis 1978b:171; Thomas 1982:3), each one rising in succession from the same point on the horizon and following "the same road" as its predecessor.

Thomas was told that a navigator knows about 150 stars and constellations (Thomas 1982:3). Alkire (1970:47) reported Woleai navigators to possess 270 separate pieces of information, while Gladwin (1970:131) recorded 110 separate round-trip courses known to his informants. This is indeed a formidable body of knowledge, especially since each course was available to the navigator in discrete form rather than as part of a mnemonic sequence! Thus, as a voyage progresses, the navigator uses a succession of stars of the same rising or setting azimuth. This star course or path has been called a "linear constellation" (Kursh and Kreps 1974:334; Aveni 1981:162) and is a unique astronomical concept unknown in the classical West. During the day the sun or swell patterns are used as directional guides. The sun's position with respect to various vessel and rigging parts as well as its azimuth is employed. Its bearing is checked against the stars before departure to determine its current orientation. Under overcast skies, swell patterns are enough to guide the experienced navigator, though the magnetic compass is now common on Micronesian canoes and is often preferred for daytime steering but not initial course setting, which is still done by the star compass. Finally, backbearings are taken as an island is left behind to check for leeway and offsetting currents and corrections are made. Mid-

course islands and reefs may provide checkpoints along the way (Gladwin 1970:154-155, 161, 165, 179; D. Lewis 1972:106; Thomas 1982:4, 7).

No attempt will here be made to fully explain all the often complex elements of Micronesian navigation such as the use of bird flight paths and swell patterns, sea marks, Marshallese stick "charts," wave refraction and reflection and more. The interested reader is referred to the bibliography, especially to the works of David Lewis, Gladwin, Thomas, Grimble, and Dodd. But one navigational technique found only in the Carolines deserves mention because it uses compass stars in an unusual way. This system, known as etak, allows a navigator to determine by dead reckoning how far along a given course he has sailed. It is a way of fashioning a conceptual map of the journey by synthesizing canoe speed, time since departure, astronomy, and geography (Gladwin 1970:184).

Each traditional set of sailing directions includes a "reference island" which lies between the starting point and destination, but well off the direct line. This island is not, in fact, visible during the voyage. The navigator "calculates" his position as he sails along by imagining his own canoe to be stationary while the reference island "moves" under a succession of compass stars (Gladwin 1970:183-187; D. Lewis 1978b:145). As the island "moves" from one star to another, an etak, or segment, of the voyage is completed. However, there are two exceptions to this pattern. The first segment of the voyage, from departure until the island disappears from view, is called the "etak of sighting." The second stage, the "etak of birds," corresponds to the feeding range of birds

roosting on the island. The last two segments of a journey are similarly designated (Gladwin 1970:188).

This same concept of "moving" islands is applied to tacking. In this case, the destination island "moves" to and fro under the compass stars as the canoe crosses back and forth over the direct line course (Gladwin 1970:189-193; D. Lewis 1972:139). Similarly, this notion might be used to keep track of one's position if blown off course (D. Lewis 1972:141).

To the Western mind, so influenced by our capacity for instrumental precision, the efficacy of a system devised by loinclothed men sailing outrigger canoes may seem doubtful. The proof of their prowess as sailors lies in their presence on far-flung islands long before European "discovery." And the accuracy of their navigation is, for those who desire independent confirmation, attested to by the reports of early European explorers as well as more recent investigators. Père Paul Clain reported the arrival in the Philippines in 1697 of 29 people after a 70-day voyage from Palau. One claimed to have been to Mindanao before (Parsonson 1963:33). The Spanish, who chased the indigenous Chamorros from the Marianas in 1686, noted the antiquity of the links between that group and the Carolines where the refugees presumably fled. A century later, when contact between the groups was renewed, the Carolinians knew the star course between the two chains. Since the late 1960s, there have been several round trip voyages between the Carolines and the Marianas, navigated strictly by indigenous methods, sometimes with Western observers on board (D. Lewis 1978b:162-163, 177-180).

Though voyages between the eastern and western Carolines had

reportedly ceased by the time of European discovery (U.S. Office of Naval Operations 1944:115), the German South Seas Expedition before World War I collected sailing directions to the Philippines, the Marianas, the Marshalls (to the east of the Carolines) and northern New Guinea (Åkerblom 1968:115). At the behest of these same ethnographers, a navigator from Puluwat who had never been to Ponape in the east made the 625 km journey using the traditional star course (Lewthwaite 1967:76). Gladwin (1970:37-39) reported 73 trips made by 15 large Puluwatan canoes to destinations between 25 and 250 km away, all between January 1966 and April 1967. The purposes of these voyages varied. Some were to gather turtles from an uninhabited speck of land 160 km distant, others to buy tobacco, and yet others simply to visit. While these voyagers may take to the sea in essentially open craft for what would be called whimsy in the West, they are completely cognizant of the inherent dangers. The sturdiness of their vessels and efficacy of their navigation find support in Gladwin's (1970:63) report that the last Puluwat canoe lost at sea disappeared during a typhoon in 1945.

Both indigenous tradition and the historical record are replete with accounts of long distant navigational feats throughout the Indo-Pacific region. Unfortunately, the details needed to fully describe and evaluate the navigational practices are usually lacking. The centuries of Western intrusion have diluted or erased much of local culture. The spiritual, highly secret nature of navigational knowledge in many areas made it the exclusive province of a restricted group within the society. As a result, it was easily lost in the wake of cultural upheaval accompanying European discovery (D. Lewis

1974:136). Many early written accounts of these practices were vague or sketchy, either because the recorder did not understand or was misled, intentionally or out of ignorance, by an informant. For example, Hornell (1936:25) cites an earlier report by David Malo that in Hawaii, the stars were used as a compass. This, alone, is clearly insufficient for comparative purposes. Other tantalizing bits of information are left us by early European explorers of Polynesia. In the late eighteenth century Andia y Varela described the sun, stars, wind, and waves as guides allowing navigators to lay courses to individual harbors and not just islands. Cook's third voyage produced similar, but more skeptical, reports (Beaglehole 1967:164). Nonetheless, enough data are available to trace the thread of Carolinian-like sidereal navigational across the Indo-Pacific region and weave a plausible fabric of possible relationships.

From many parts of Polynesia and its Melanesian 'outlier' islands comes evidence of star path or linear constellation navigation. Across this whole area, such a grouping was called kavenga or some variant thereof (D. Lewis 1972:passim, 1978b:passim; Best 1922:28; Dodd 1972:49; Kyselka and Bunton 1969; Ellis 1931:168). But there are also hints of what could be sidereal compass remnants, though no representational evidence has been found. On Tonga, an elder of a traditional clan of navigators named "eight star points indicating directions rather than the positions of islands ..." (D. Lewis 1978b:76). These had been learned from his father who reportedly knew more than he. Andia y Varela found a 16-point compass rose in use on Tahiti near the end of the eighteenth century, east being the principal direction (D. Lewis 1964:365). It should be added

that the wind rose per se was well known in the region, as in ancient Greece and Persia. The Maori of New Zealand and the Reef Islanders, Polynesian inhabitants of geographic Melanesia, used 16-point and eight-point wind compasses (respectively) to name but two examples (D. Lewis 1978b:44; Best 1922:30).

Interesting evidence has also surfaced on the island of Hawaii. A recently-surveyed heiau, or temple, on a raised platform located on a high plateau seems to have been an astronomical register also functioning as an indicator of terrestrial direction. From its center one could observe the rising or setting of important celestial bodies by sighting over stone markers. The various celestial events had calendrical as well as navigational significance (Da Silva and Johnson 1982:313-322). Also from Hawaii have come legends of a "sacred calabash" or gourd compass. According to some accounts, this device was filled with water, its rim perforated in precise locations to allow the user to sight a star through one of the holes and over the opposite rim, thus determining when a vessel was in the latitude of Hawaii (Rodman 1928:82, 84). Johnson and Mahelona (1975:72-74, 142-153) include accounts describing holes and knots along the rim and a meshwork over the top. The gourd would be aligned using the holes and the reflected passage of stars and planets observed in the water, the netting serving as a reference. It was also described as a teaching tool in an 1865 account with no mention of shipboard use or water within.

Long debunked by scholars (D. Lewis 1972:238n.6; Bunton and Villier 1963:8; Dodd 1972:43) due to the vague or fanciful descriptions and exaggerated claims of some sources, the gourd compass gains new

plausibility when taken for a representation of the cosmos with calendric and directional functions. The incised lines of some accounts represent the limits of seasonal solar and lunar movement along the horizon while rim markings denote azimuths. So arranged, it might clearly have been used as a teaching or memory aid for what could just as easily have been a purely mental construct (Da Silva and Johnson 1982:321-322).

Da Silva and Johnson have associated the gourd compass concept with the heiau described above. Unfortunately, the cairns are not sufficiently precise to allow absolute identification of the associated stars. Of those indicated, some - Altair, Orion, Pleiades, Pollux, Sirius - were named in the works on the compass cited above. The others are obviously chosen as functions of the stone markers themselves. Many are prominent bodies and three, Aldebaran, Procyon, and Spica, are included in the list of the Tahitian "Pillars of the Sky" recorded in 1818 (D. Lewis 1972:239). In A.D. 1000, these stars passed through or close to the zenith (thus indicating the latitudes) of various islands supposedly within the Tahitian voyaging realm, including Hawaii. As we will see in a subsequent chapter, at least some of the settlers of the Hawaiian chain may have come from the waters of Tahiti. Nonetheless, one must treat cautiously any claims that the gourd or the heiau describe an actual Hawaiian sidereal compass.

In Melanesia, traditions of long-distance voyaging have been found among Fijians (D. Lewis 1978b:58) and Solomon Islanders (Haddon 1937:93). In the latter case, six-day trips for "trade and pleasure" were made steering by the stars at night. It is only on Ontong Java,

another Melanesian locale whose inhabitants speak a Polynesian language, that evidence of a compass rose has surfaced; in this case, another wind rose (Fig. 5). The German ethnographers mentioned earlier recorded 28 voyaging star groups but, lamentably, no destinations. They also confirmed the accuracy of oral traditions of contacts between Tikopia and Luangiua, an island of the Ontong Java group (Bayliss-Smith 1978:43, 54-55). Local sea captains exhibited only limited knowledge but claimed that their forefathers knew much more. As in the Carolines, the constellation Mailapa, the Big Bird, was of pivotal importance. The rising times of other significant constellations were expressed in relation to that of Mailapa, eight rising before and eight after. Ontong Javans also shared a traditional Micronesian and Polynesian description of star movement. Stars were said to follow three paths, the northern, the southern, and the path of the bird between the first two (Sarfert and Damm 1929:187, 195). This is reminiscent of both Hawaiian astronomical lore and the Carolinian jaan, the common "road" said to be followed by stars of similar Declination (Goodenough 1953:4; Gladwin 1970:148; Johnson and Mahelona 1975:72).

Perhaps the most intriguing recent evidence of star compass navigation outside Micronesia comes from the island of Madura, off Java's north coast. There, older skippers retain some star navigation lore which is, however, fast disappearing, particularly since 1962 when magnetic compasses were made compulsory equipment on larger craft. Informants referred to "25 stars" basic to navigational science, their rising and setting points constituting the bintang pedoman or star compass (Fig. 6). All stressed the importance of the

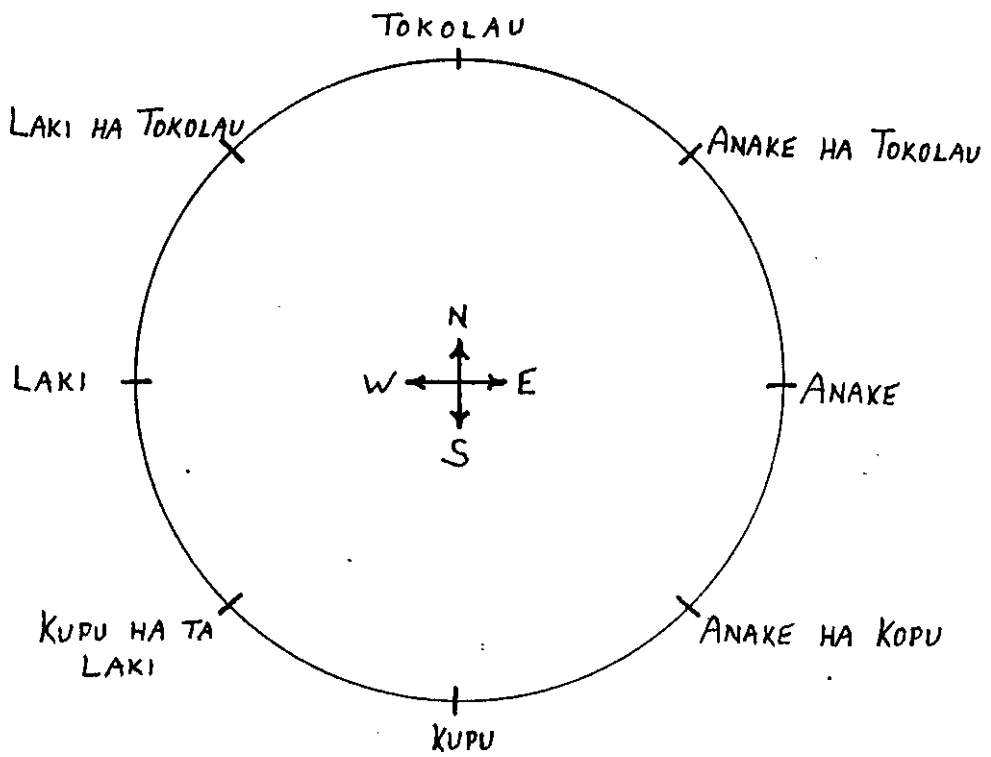


Figure 5. Windrose from Ontong Java. The winds took their names from the names of the directions.

Setting

Rising

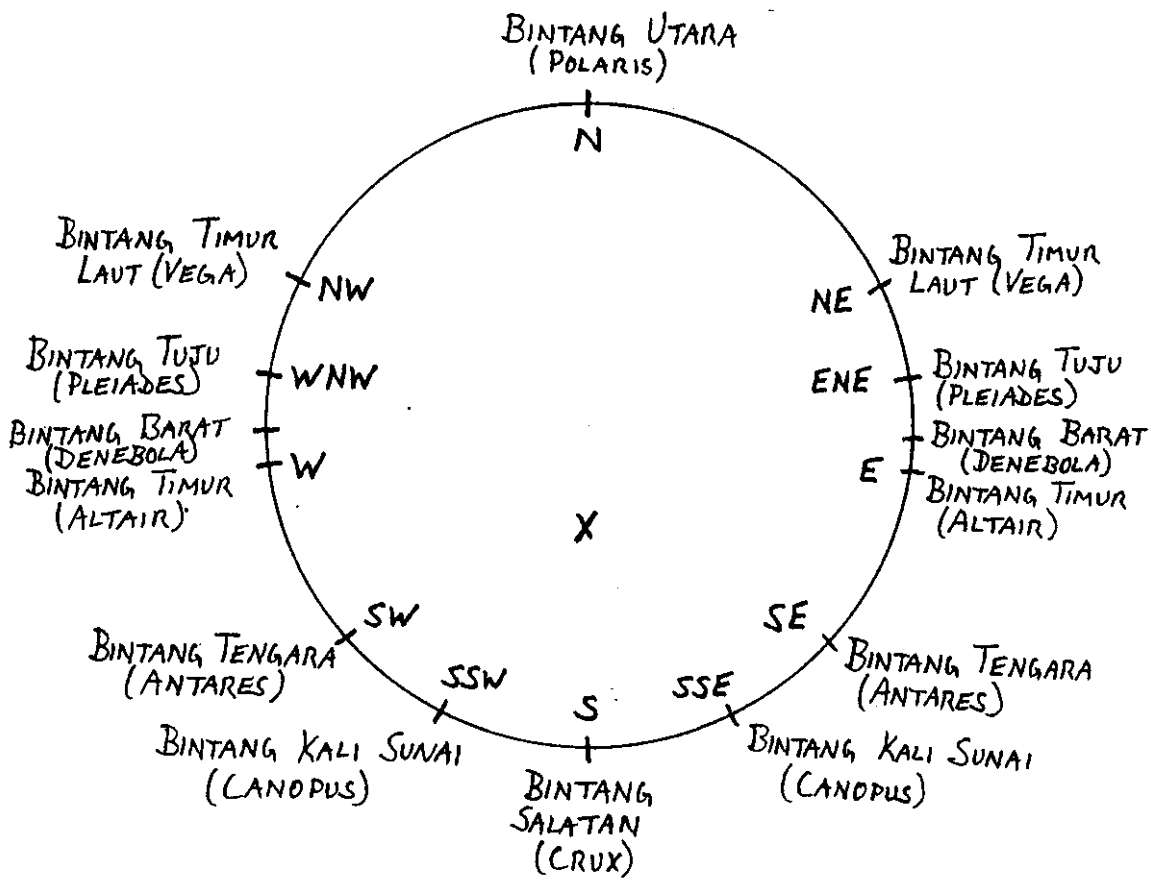


Figure 6. Madurese sidereal compass (after Liechti et al. 1980). The "X" marks the actual astronomical center of the azimuths.

eastern stars, especially Altair, though only 14 of the azimuths could be identified with any degree of certainty (Liechti et al. 1980:2-4). Swell refraction patterns, as elsewhere in the Pacific, were also included among the traditional navigational techniques as well as a calendrical function for certain stars and constellations.

Adrian Horridge, author of The Prah, has questioned some of the star names given on linguistic grounds (1984:personal communication). However, David Lewis, one of the authors of the report, defends the accuracy of the data (1984:personal communication). In fact, the names supplied by Liechti and coauthors are not star names at all but a combination of bintang, meaning "star," and other terms signifying winds or simply directions. These are quite different from the regular star names used by the inhabitants (Frake 1984:personal communication). These facts do not in any way invalidate the possibility of an Indonesian star compass. It may well be that the remembered lore of the informants is accurate but that the names of the particular stars denoting the azimuths have been forgotten. Such a star compass might have coexisted with a system of directional winds, a common phenomenon in the "inland sea" conditions of the Madurese. Another explanation is suggested by the scantier Polynesian evidence. There, wind roses may have constituted a cognitive directional system while star paths were used for actual navigation.

Javanese seafaring links to both the east and west seem certain if only because of its geographic position between the two great oceans. The navigational parallel with Oceania just noted is also suggested by Archibald Lewis (1973:252n.3). In addition, he

cites the reports of early European travelers such as Conti and Varthema who mention the use of the Southern Cross and other stars for navigation. He even attributes such discoveries to the Javanese despite Needham's claims of Chinese primacy. Lewis further defends the high frequency of direct Javanese voyaging to the Maldives and Laccadives in the Indian Ocean, and possibly to Madagascar, Africa, and the Moluccas.

Evidence from the Indian subcontinent is sketchy, at best. Pliny, writing in the first century A.D., states that mariners of Taprobane, the Greek name for Ceylon, the island now known as Sri Lanka, used double-prowed ships that could reverse direction (as do today's Micronesian outriggers) but that the stars were not consulted for navigation (Mookerji 1962:72). A fourth-century work, however, says that the Indian pilot Suparaga "knew the courses of the stars" (D. Lewis 1978b:142). Over a thousand years later Ibn Majid, the Arab navigator who supposedly revealed the secrets of monsoon sailing to Da Gama, described Indians setting their courses by northern and southern stars "and other remarkable stars which were normally found in the middle of the sky, from the east to the west..." (Ferrand 1919:160). Though the reference is obscure, the phrase could easily describe a tropical system of navigational astronomy utilizing linear constellations whose stars rise and set vertically, passing overhead or nearly so.

The great time depth of Chinese culture, literacy, and nautical technology demand a brief word on star compass evidence from that quarter. As we have seen, Chinese astronomy was primarily of the polar-ecliptic sort and included time computation by circumpolar stars

and latitude determination from the height of Polaris. But there is also evidence of the importance of rising and setting azimuths (Needham 1970:141). An anonymous rutter of 1669 entitled Chih Nan Cheng Fa, or "General Compass-Bearing Sailing Directions," includes the rising and setting points for various stars and constellations including Altair, Vega, Crux (The Southern Cross), and, possibly, Canopus. Another work, 240 years older, gives three tables of 24 azimuths and one of 14 known as "Palaces of the Heavens." A third table associates such points with the winds (Needham 1971:583). Though there is no explanation of their navigational use, it seems like that the Chinese, too, were in possession of a directional system based on stellar azimuths and were mindful of its nautical importance.

The inhabitants of the southern Arabian Peninsula have a long history of seafaring in the Indian Ocean (see Fig. 2). Sometime between the sixth and third centuries B.C. they gained control of shipping across its waters. The south Arabian coast and adjacent island of Socotra became entrepôts on the routes between India and Egypt. They commanded these sealanes for 1000 years, planting colonies in Ceylon and possibly reaching the Far East by the first or second century after Christ (Hourani 1951:21, 23; Tibbetts 1956:204). The origins of these exploits are hidden in the remote past, though Clemesha (1943:116) claims they had knowledge of the alternating monsoon seasons allowing direct sailing to India millennia before its literary revelation to the West in the first century A.D. Periplus Maris Erythrei.

Arab navigators were guided by the stars in ancient times and retained such practices even after the introduction of the magnetic

compass (Taylor 1957:128). At least as early as A.D. 851, an Arab text describes wind direction in terms of stellar azimuths. At about the same time, the north pole was referred to as the decidedly nautical "pole of Banat Na'sh", here identified as Alpha/Beta/Gamma/Delta Ursae Majoris (de Saussure 1928:119-122). There are indications from Libya and the western Sahara that this tradition was shared by or even originated among terrestrial "navigators" (Tolmacheva 1980:185). Ibn Majid refers to some stars, including Antares and Achernar, as directional or latitudinal guides "on land and sea" (Majid 1971:108; Grosset-Grange 1972c:39). In 1961 the BBC reported Bedouin navigation of 1° accuracy over 650 km of desert (Parsonson 1963:42), though such wayfinding probably included non-celestial elements.

Today there is virtually no high-seas sailing by Indian Ocean Arabs, whose navigators have not relied on the stars since the early nineteenth century. Sextants are common except in the Maldives and even the long-used sidereal calendar has fallen into disuse, though it is still known in the Comoros and Madagascar. Klunzinger, however, writing in 1878, noted that Red Sea Arab helmsmen steered by the stars whether they had a compass or not. Interestingly, Arab compass points are still designated by star names rather than (or in addition to) Western bearings or degrees (de Saussure 1928:93n.1; Grosset-Grange 1972a:47-48, 57-58). An illustration of such a compass (Fig. 7) was copied by Prinsep (1836:Plate 48, 788) from the Majid Kitab, a commonly used Arab navigational treatise of the day named for the then still-famous fifteenth-century pilot. The system is described in the Muhit, a sixteenth-century work by Turkish admiral Sidi Ali Çelebi,

Setting

Rising

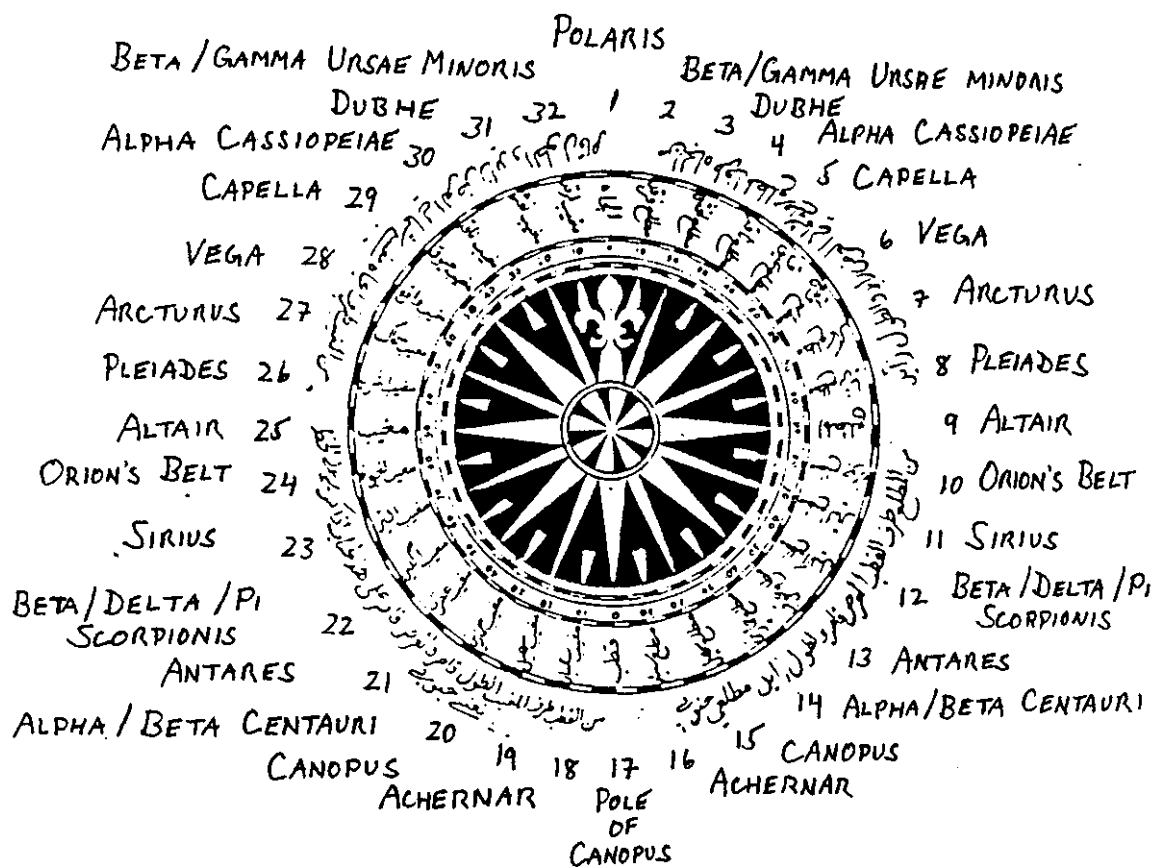


Figure 7. The Arab sidereal rose as it appeared in the early nineteenth century. The four phrases around the circumference describe changes in latitude and longitude (e.g. latitude increasing, longitude decreasing) experienced by a mariner moving in a given direction (after Prinsep 1836; Tibbetts 1971).

extracts of which appeared in the Journal of the Asiatic Society of Bengal (Von Hammer 1834:548, 1838:768-769). This work was apparently only an adulterated version of fifteenth- and sixteenth-century rutters by Ibn Majid and Sulaiman al-Mahri who, themselves, built upon a published nautical heritage dating to at least the tenth century (Ferrand 1928:198, 225; Tibbetts 1971:296).

Two unusual aspects of this compass rose spring immediately to the fore in comparison to the Carolines compass: 1) the numbers indicating bearings in degrees within the circle of star names and 2) the regularity of the azimuth spacing. Both these features probably indicate the adaptation of an older system of sidereal bearings to a European-type compass rose, though others have offered differing explanations. De Saussure (1928:104) maintained that the lack of correspondence between compass rhumb and star azimuth derived from the necessity of using the brightest stars visible at the horizon. Majid's attribution of the discrepancies to "convention" probably supplied the basis for de Saussure's position. But his successor, al-Mahri, supplies the names of other stars whose positions more closely matched the rhumbs. Tibbetts (1971:298) concludes that these latter stars were not, in fact, used because they were mostly "obscure" or unidentifiable. He also reports extra stars near the east-west line as part of a system of latitude sailing akin to the European "raising the pole" (Tibbetts 1971:298-299; Taylor 1957:163-164). We will discuss another interpretation of these anomalies in Chapter IV.

Grosset-Grange (1972a:57) attempts to explain the Arab use of half or quarter points lying between the rhumbs designated by star names. But his exposition, given "with reservations," fails to reveal

his reasoning and is not at all convincing. No doubt contemporary Arab navigators and perhaps their predecessors designated such intermediate azimuths. However, the background and use of this system remain obscure.

The representation of the Arab rose also shows striking similarities to the Carolinian system. It shares fully 18 star points of the total 32 with the Micronesian compass. Just as in the Carolines, the azimuths in the eastern half of the rose are labelled "rising place of" (matla in Arabic), while those in the west are designated magib, "setting place of." Further, Arab navigators spoke of setting courses on the names of stars rather than degrees, even when the latter were available (Prinsep 1836:788-789). From these stars, Tolmacheva (1980:183) concludes that the Southern Cross indicated south. While this is possible, even probable (we will discuss Arab use of this constellation below), there is no internal compass evidence presented to support this contention. Unfortunately, little is known of the Arab use of horizon stars. The literature on trans-Indian Ocean Arab navigation has been dominated by discussions of various forms of latitude sailing by the height of Polaris and other stars since before European penetration of the region (Prinsep 1836, 1838; Von Hammer 1836, 1837; de Saussure 1928; Ferrand 1928; D. Lewis 1978a:61; Grosset-Grange 1978). It seems clear, however, that a very old sidereal compass system was also at the heart of their seafaring repertoire.

How are we to interpret the different star compass systems and various tantalizing hints of common navigational practice across the Indo-Pacific region? Did they all spring from a common source? Are

some few related while others arose independently? In order to answer these questions we must carefully analyze the often-scant data available, paying close attention to geographical as well as temporal factors. Evidence of an archaeological and ethnologic nature will be marshalled. In addition, the astronomical elements of the various systems will be explained from both mathematical and cultural standpoints. Before we embark on this task, however, a theoretical and methodological discussion of diffusion versus independent invention of cultural traits will be presented.

CHAPTER III

THEORY AND METHOD

The central question of this investigation is that of the origin of the Carolinian sidereal compass. More specifically, we will attempt to determine the nature of the development of this navigational construct. Was it "invented" in Micronesia, unaffected by systems of wayfaring at sea from other parts of the world? Could its obvious similarities to sidereal compasses from remote locales be coincidence, an example of cultural convergence or parallel development? Or can its heritage be traced to and linked with these other compass systems from the Arab world, the Pacific, and Indonesia?

The ongoing argument between supporters of diffusion and those favoring independent development as an explanation of cultural similarities is an old one in anthropology. The theoretical and methodological implications of these two approaches are both interesting in and of themselves and important for establishing a framework within which evidence on the compass problem can be examined. Without such grounding, analyses of the data remain unguided, difficult to test and compare to alternate conclusions, and less likely to contribute to broader notions of cultural change and human nature (Fraser 1964:452-453).

Despite the importance of sketching such a theoretical framework and using it to analyze the data, the task is by no means straightforward. One stumbling block is the paucity of hard data applicable to the compass problem. This will be addressed in detail

below. The more serious hurdle is that posed by the very state of anthropological theory in the realm of diffusion. No generally accepted standards exist against which a given set of data may be measured. Evidence accepted by some as irrefutable proof of diffusion is often dismissed by others as inconclusive or even as unshakable testimony for the cause of independent invention and development. Fraser (1965:453), citing George Kubler and Robert Heine-Geldern, notes that similarities between the Asian game pachisi and the Mexican patoli have served both sides of the argument. Maya pottery and late Chou bronzes have been used in the same manner. Their stylistic resemblances "prove" either the existence of links between the two cultures or a wonderful convergence, since such links could not exist (or, at least, have not been demonstrated) over thousands of miles of ocean and ten centuries of human artistry.

A priori perspective and expectation seem to rule the field. Thus, Fraser attributes much of the present dilemma to the "inherently ambiguous" nature of the problem. We cannot, here, delve deeply into the theoretical or philosophical roots of the nature of objective versus subjective knowledge or the notion of causality in human affairs (though causality will be addressed briefly below). These are broader philosophical questions beyond the scope of this effort. Though today's anthropologist and archaeologist often borrow procedures from the realms of biology, physics, and chemistry, we should follow Karl Popper's warning against confusing scientific method with determinism. Social science differs from natural science not in method but in the nature of the phenomena studied (Evans-Pritchard 1961:18). Expanding upon Fraser, one might say that all

human activity is inherently ambiguous. This in no way solves our problem. But it does limit or, perhaps, we should say refine, our expectations of the theoretical precision we are likely to obtain.



Given that caveat, we can outline certain tenets on both sides of the diffusionist-independent inventionist debate in hopes of attaining a workable set of criteria with which to analyze and judge our data. Here, too, however, we must remember that not all observers will agree on even the most promising or powerful theoretical assumptions. The debate is often over precisely the applicability or worth of these assumptions. Even if we might devise a means of filtering from our structure the most insidious of personal predilection, the "inherent ambiguity" of our phenomena will again creep in to color the interpretations.

There are a number of possible ways to explain close similarities of cultural traits in two or more different cultures. The groups may have invented them completely independently (encompassing the notions of parallel and convergent evolution). Or one group may have influenced the other. This influence could come about through migration, trade contacts, by the intermediary of another or other cultures having contact with the groups in question, through warfare, or even casual, chance encounters of members of the groups. Any such contacts could lead to stimulus diffusion. Another possibility is that both groups may have sprung from a common ancestor. Of course, the details of a particular situation would render more or less likely any or all of these scenarios.

Negative postulates are difficult, if not impossible, to prove outright. Imagine the task of presenting evidence to conclusively

eliminate the chance that Culture A had influenced Culture B despite certain similarities between the two! One would have to prove the physical impossibility of contact due to spatial or temporal barriers. Still, independent inventionist explanations for cultural parallels offer valuable guidelines which cannot be ignored.

Inventionists usually stress the universals of human existence to explain cultural parallels. Our common physical and psychological makeup, our tendency toward inventiveness, and the common nature of the problems of survival we face all contribute to the reproduction of cultural "solutions." More specifically, similar social and economic histories, especially when set in similar environments, often lead to cultural parallels (Jett 1978:594). In other words, "human nature" and/or functional needs inspire parallel responses under similar conditions. Further, the great variety found in complex societies increases the chance of random repetition of a trait (Rands and Riley 1958:275). Thus, even groups of similar traits in widely separated cultures are not necessarily indicators of contact or diffusion. Once the "nucleus of a trait cluster" has become established, a sort of sequential imperative guides the development and elaboration of the cluster as a whole, leading to complex cross-cultural similarities. This elaboration is governed by the limitation of possibilities born of similar environments and has been termed "complex demand." One example might be the blowgun complex of Southeast Asia and the Americas (Rands and Riley 1958:277-278, 280). Trait clusters are particularly significant in this schema. Complex demand and the question of whether or how other cultural factors might have influenced the convergence of traits must be addressed in each case

(Rands and Riley 1958:282-283). In addition, it is argued, even if two societies share certain features that might be linked, the existence of similar, unrelated traits elsewhere militates for an inventionist interpretation. Great weight is also placed on central or "significant" traits when examining a case of possible diffusion (Rowe 1966:334; Fraser 1965:460). The existence of an isolated case of formal or even conceptual similarity is not enough to prove or even strongly suggest contact. For example, in an instance of certain non-contact, ancient representations of the number 12 among the Maya () and the French () comprise nothing more than a striking coincidence (Caso 1964:55, 58).

The two most important parameters for the analysis of trait origin are time and space. Evolutionist proponents focus not only on evidence of the sequential development of a trait within a culture but also on the relative dates of similar traits in different cultures. Thus, stratigraphy (in the case of archaeology) and historical documentation assume pivotal importance in any investigation. The inventionist usually requires that the contributing culture display a trait contemporaneously or only slightly earlier than its appearance in the receiving culture for diffusion to be considered. Spatially, equally stringent criteria are applied. Discontinuous distribution of traits is often seen as a priori proof of independent invention unless a strong case can be made for the former existence of intermediate links or subsequently reduced broader distribution that would bridge the gaps. Another condition necessary to convince the evolutionist of possible diffusion is absolute evidence of contact between the two cultures (including, of course, a reliable means of conveyance). In

the extreme case, this requirement might be as stringent as archaeological proof of trade or colony sites or repeated trade object occurrence (Rowe 1966:336; Fraser 1965:460).

These principles have been used in opposition to frankly diffusionist interpretations of cultural similarities for many years, nowhere more vociferously than in the argument over Transpacific contacts. Examples from this realm will be used below to contrast the two schools of thought as working models for the understanding of past events. Further, a synthesis will be attempted to provide a convenient framework for the interpretation and analysis of our own data. First, however, the general tenets of the diffusionists must be outlined.

Jett (2978:495) has summarized nicely the main points of the diffusionist approach. As opposed to the evolutionists' emphasis on the universality of the human conditions and subsequent frequency of common response, diffusionists tend to see each culture, taken as a whole, as unique in a synchronic frame. The culturally conservative and traditional outweigh the creative and innovative forces. And any complex alteration stemming from an historico-environmental conjunction is unlikely to be duplicated. In other words, postulating a single instance of invention followed by a spread to other groups is a much more economical explanation for complex similarities than that of repeated invention. Rapid innovation is seen as rare and usually linked to contact with another group.

Here, again, time and space are the crucial parameters, though a more flexible approach is common. One looks for temporal overlap between cultures as well as clustering within the receiving culture.

A significant signpost might be a developmental sequence in one group and the sudden appearance of the final stage elsewhere, though it will be seen later that there could well be important exceptions to this rule (Jett 1978:599; Meggers 1964:512; Ekholm 1964:498). Jett (1971:20, 22, 46) has also made the trenchant observation that physical and cultural barriers to diffusion are often more telling than distance per se. Especially in the case of transoceanic diffusion (discussed at greater length below), areas of low accessibility or little interest are easily bypassed. The vagaries of wind and current-affected water transport, whether drift or under conscious control, are apt to produce gaps in trait distribution essentially different than those on land. It is essential to remember that early land travel was frequently more difficult and more dangerous than sea travel!

Of course, even given the proper temporo-spatial conjunction for trait diffusion, numerous other factors influence the actual transfer of cultural material. One is the nature of the contact - hostile or friendly, a few individuals or en masse, exploratory, for trade or religious proselytization. The relative congruity of the value systems and technological attainments of the cultures may also affect trait sharing. It is often assumed that transfer takes place from materially more advanced to less advanced groups. But numerous instances of the reverse could be cited: witness the adoption of indigenous American food plants by Europeans. The nature of the trait itself is also an important factor. Is it functional to the receiving group? Does it enhance material or spiritual well-being? Does it conflict with the existing value system (Jett 1971:21)?

Many of the specific criteria used by the inventionists are also applied by diffusionists. Where the possibility of cultural response is limited, one can expect to find convergence. For example, genealogical descent can be figured in only a few ways: matrilineally, patrilineally, or bilaterally. Similarly, the disposition of human remains offers limited choices: land, water, or aerial burial, cremation, mummification, etc. Clearly, a much greater degree of specificity or uniqueness would be necessary in these domains to make a good case for diffusion. In fact, they argue, such generalized and basic cultural phenomena are probably not good yardsticks at all and should be avoided. Much more useful would be traits that are arbitrary, not engendered by human nature or the functional demands of the environment. The best indicators of diffusion are similar traits in dissimilar contexts (especially an associated cluster of such traits). Examples include specific lexemes or the association of a particular animal with a day of the week or month (Jett 1971:32-33, 1978:598-599; Kelley 1971:61; Meggers 1964:512).

While it may be said that both diffusionists and independent inventionists often analyze the available data using common parameters, it can easily be seen that the criteria of the latter (as outlined above) are often used to restrict or disprove the claims of the former. There is sharp, often vituperative disagreement. Initial assumptions aside, we must examine the application of such criteria to evaluate the predictive power of the framework they exemplify.

The Pacific Ocean and the lands strewn across its surface and defining its perimeter have been a battleground in the struggle to

trace the history and prehistory of its peoples. The origin and development of American societies, especially the "high" cultures, have served as a major focus of attention. Diffusionist claims of Chinese influence in this process often draw pointed attacks from those who argue for indigenous inspiration to explain the great cultural achievements of the Americas. Though these arguments do not touch directly on the peopling of the Pacific islands, the long-distance, oceanic nature of the postulated contacts offer an appropriate field for testing certain diffusionist propositions and inventionist objections. (We do not propose to settle the arguments over Asian influence in the Americas but to employ them in the search for useful criteria against which to measure our own data.)

The absence of significant Old World traits in the Americas is often seen as proof that diffusion did not occur. Where are the wheeled vehicles, the true arch, the plow, draft animals, and milking? ask the critics. Surely, such important discoveries of Old World civilizations would be among the first introduced into the Western Hemisphere. But examples of similar absences in known contact areas eliminate this criterion as a sine qua non of diffusionist proof. Within the Old World, these same traits failed to appear in certain areas of sub-Saharan Africa despite their existence among North African Islamic societies and the influential presence of Muslims south of the great desert (Fraser 1965:460). In Asia, the Khmer probably knew the true arch but used the corbel system at Ankor. And within the New World the use of the corbel arch never stretched beyond the boundaries of Mesoamerica despite Maya contacts with Teotihuacan (Ekholm 1964:501).

In the important realm of domesticates, George Carter (1974:211) has cited E.D. Merrill's argument that major food crops would be the earliest travelers. But evidence from post-Columbian times lends little credence to this notion. Successfully diffused crops have included cocoa, quinine, tobacco, and grapes, all specialty items. Staple crops often meet with resistance precisely because of their importance. Successful diffusion would mean replacing an already familiar mainstay among the great mass of people, no easy task. One can see a parallel in lexico-statistical analysis of loan words. Those central to basic home life - the so-called "hearth" words - are usually the most resistant to change. Successful transmission of a trait depends on the ability and willingness of the recipient culture to incorporate it. In Egypt there was no use of the wheel or true arch for 1000 years after other transformations induced by contact with Mesopotamia. It must also be remembered that the nature of the transmitting group can affect the form of the trait. A dissident group might well transform shared cultural elements (Kelley 1971:61-62).

Clustering of traits is another important factor in the analysis of both diffusionists and independent inventionists. It provides stronger evidence of contact than isolated traits and offers a convenient check on the construction of fanciful edifices of diffusion on the flimsiest of foundations formed by a few scattered similarities. But it must be used with care! Ekholm (1964:503) has pointed out that the well-documented Chinese contributions to European civilization (e.g. paper, the crossbow, compass and, according to some, the magnetic compass) were not in the form of clusters and

emanated from no single dispersal center in Europe. Without the historical record, the process, if not the very origins, might be lost to us. Thus, the mere absence of clustering cannot be used to disprove contact. Fraser (1965:466-467) has mentioned other pitfalls of the clustering phenomenon in his discussion of Kubler's attacks on diffusionist ideas. Kubler argued that the resemblance between Chinese bronze scrolls and Ulúa pottery scrolls was "adventitious" because both forms were single elements in completely separate series of unrelated and dissimilar origins. Thus, two temporal series of forms (clusters) can include individual resemblances without being related, provided each cluster is a true sequence with each form growing out of its predecessor and no possibility of "cross influence" exists. While the main argument remains valid, this last point begs the question. It is precisely this possibility of contact we wish to prove or disprove.

Another important notion, the existence of a developmental sequence, especially when coupled with the sudden appearance of the final stage in a different location, must be handled adroitly. It is a powerful tool for investigating possibilities of diffusion, but the mere presence or absence of a sequence in no way closes the case. Stimulus diffusion (leading to the adoption of a form without the borrower understanding the content or process) can create a false developmental sequence in a recipient culture. The adoption of each stage over time mimics the development process of the donor culture. On the other hand, a true developmental series can be masked if the early stages (in the case of material traits or their representations) have been executed in perishable media which do not survive. The

final, permanent stage(s) might appear to be borrowed from elsewhere (Jett 1971:45). However, it must be noted that the first scenario seems not the stumbling block that Jett would make it. If two cultures were in close enough contact to allow the diffusion, step by step, of an entire developmental sequence from one to the other, then surely there would be other evidence warning of the close ties. The mere existence of the two identical series should alert the careful observer to the strong possibility of diffusion.

Fraser (1964:462-463) has neatly outlined the logical pitfalls of using the existence of unrelated parallels to question the notion of contact between two cultures exhibiting similar traits. If the trait be very widespread, it is too common to be a significant test of diffusion. On the other hand, only a few widely separated venues for a particular trait reduce the probability of contact virtually to zero. Both instances argue against diffusion but for different reasons requiring different logical procedures. In the first, one must demonstrate "non-relevance to context." The second demands that the researcher "exhaust the possibility of transmission." Both sides of the diffusion question must follow this methodology to seal the case, says Fraser.

Trait distribution is another arena of frequent conflict. Contiguous areas showing similar traits are generally assumed to be linked. But one can cite Ecuador and Mesoamerica as an example of discontinuous distribution born of a 2000 mile maritime trade that is widely accepted. It would hardly be equitable to admit this intra-hemispheric link while dismissing similar Transpacific diffusion out

of hand (Fraser 1965:463-464). Other examples of known discontinuities may be given. Greek influence in Han China and Mexican traits in the southeastern United States are accepted despite the lack of corroborating trade objects and our inability to trace the path of transmission (Jett 1971:31). Similarly, ocean voyages can easily miss isolated islands. For instance, a certain type of Y-shaped outrigger connective system is common from Micronesia to New Caledonia. But a curious gap in the distribution exists between that island and Sikaiana (Haddon and Hornell 1938:78).

Here, a crucial point for our investigation must be made. Given suitable watercraft, the sea is not a barrier to contact but a highway. Seen in this light, transoceanic and island scattering of a trait do not constitute a break in distribution at all. We cannot live permanently on the open sea. Thus, an intervening ocean does not represent a discontinuity. And the very nature of sea travel, as opposed to movement on land, renders island lacunae in the chain of traits all the less anomalous.

This raises the question of a means of transport. This is not nearly so thorny a problem in the case of overland transfer of traits, even over great distances. But transoceanic diffusion is quite a different matter. Independent inventionists have rightly required proof of at least the possibility of a reliable water transport system. Some have demanded the tracing of specific routes and the enumeration of way stations. However, as Fraser (1965:468-469) has pointed out and as was mentioned in the discussion of distribution (above), sea travel is "linear" rather than "planar" and often leaves no traceable track. For example, all evidence points to the

settlement of Madagascar from Indonesia. Yet the Indian Ocean islands reveal few signs of this migration. On the other hand, the mere existence of adequate watercraft is no proof that a voyage ever linked two given locations: witness the Heyerdahl Kon-Tiki expedition. Nonetheless, recent archaeological and anthropological investigation has gone a long way toward dispelling the reluctance of even the staunchest inventionist to accept at least the feasibility of long distance sea travel by so-called primitive peoples in the Pacific and elsewhere (Sinoto 1983; D. Lewis 1972, 1978b; Finney 1979a; Heyerdahl 1980; Bass 1972, 1976). We will examine in detail this early seafaring capability in a subsequent chapter.

One seemingly useful criticism of diffusionist methodology is that traits are singled out for comparison rather than each culture being treated as an integral whole. This is valid if it refers to selecting traits in such a way as to avoid contradictory evidence. But while a culture can be usefully treated as a functional unit in a synchronic view, as soon as time depth is introduced, the divergent temporal and spatial origins of the various components of the whole are clearly visible. The unity disappears in the diachronic scheme (Fraser 1965:469).

Hard evidence of contact often takes the form of material objects of one culture discovered in the precincts of another. This is the kind of "proof" Rowe wanted (above). But we have already seen instances of contact without tangible corroboration. In Egypt, written accounts tell of contacts not reflected in material finds. Strong evidence of a Peru-Mesoamerica link exists as well as one between Mexico and the southeastern U.S. despite the lack of trade

objects. Material culture is only a partial reflection of the entire society. Too, the archaeological record is often incomplete (Ekholm 1964:499). Many now accept a much broader range of evidence in support of diffusionist interpretations: botanical, genetic, linguistic, and ethnological (Jett and Carter 1966:868). This expanded field of evidence opens the way to a more subtle understanding of the nature and significance of cross-cultural contacts. The importance of such links rests not on the mere fact of contact but on the cultural influence of one party on the other. Were this not the case, the Buddha figures found in Scandinavian graves would mean far more than they do (Fraser 1965:462).

Many diffusionist-inventionist disagreements turn on the interpretation of artistic styles and motifs. One area of conflict is whether a particular motif draws inspiration from another culture or is simply a representation of a natural phenomenon familiar to the artist. Examples include animal and plant motifs (often abstracted), especially in complex combinations. For instance, serpent-bird combat is a familiar theme in Europe, the Americas, and Oceania. Fraser (1965:471-472) argues, unconvincingly, that most art is inspired by other art not by nature. The matter must rest theoretically unresolved at this stage. But in celestial navigation we find an art-science whose inspiration (the apparent movement of the night sky) is at least visible in one manifestation or another, to all cultures. In a subsequent section we will explore further this possibility of universal inspiration.

Treating convergence versus diffusion as explanations for Old World-New World art motif parallels, Fraser (1965:473-477) makes

several points having broader implications. Asian art was the product of many, diverse influences. In certain instances, New World art was "of similar manifestations subsequent in time and [followed] the same general sequence." It would be impossible to explain the American manifestation by independent invention and convergence without granting its perpetrators far more creative power than those in Asia, given the former's lower level of technology and briefer time for the development. In another case, he criticizes the attribution of Northwest Coast-Mesoamerican artistic similarities to convergence when the two areas are remarkably different in environment and the two cultures as disparate as night and day. How, Fraser asks, can a theory predicate convergence on similar foundations in some cases and dissimilar bases in others? Nor is it logical to attribute the Northwest Coast phenomenon to diffusion (from China) while refusing to admit the same potential inspiration in Mesoamerica. Broadening the scope of his attention, Fraser recalls the now-rejected theory of independent evolution and parallel development, the mainstay of nineteenth century anthropology's explanation of the simultaneous rise of Egyptian and Sumerian civilizations. Even such independent inventionists as George Kubler admit such important cases of Old World cross-fertilization. But in the case of Transpacific contacts these same people embrace a set of theoretical assumptions they have rejected within the realm of the Eastern Hemisphere. The ocean crossed, they adopt anew the diffusionist mantle to explain a host of intra-American parallels. Erland Nordenskiöld (1931:57), another inventionist, has realized the logical inconsistencies:

If we admit that the same inventions may have been

made both in the Old World and in America, it would be illogical to suppose that similar inventions cannot have been independently made in different regions of America. To me it would seem even more natural that two people of similar culture and living under similar conditions should be able to evolve some identical invention, than that it should happen to be made by peoples of different civilizations and in different environments.

Once a means of crossing has been found, there is no logical reason to assume water a barrier to the transmission of culture or to the integrity of theory.

There are a number of obstacles in the path toward a coherent analysis and useful synthesis of the arguments presented so far. Great gaps exist in the archaeological record. Diffusion can follow devious routes and styles could conceivably be maintained for centuries in perishable forms only. The scientific method stresses induction from certainties. The painstaking accumulation of archaeological and ethnographic data normally does not encourage workers to make great speculative leaps. And specialization in area studies often hampers a broader view (Ekholm 1964:491, 498). The isolationism that characterized American anthropology for so long encouraged a sometimes venal defense of one's special domain as autonomous and inventive (Adams et al. 1978:504). Any attempt to inject outside influence was seen as denigrating the cultural capacity of indigenous peoples.

Some have used probability theory to argue against the

independent development of similar traits in widely separated groups. One estimate of the odds of reinvention of a trait was 1 to 10^{17} (Jett and Carter 1966:868; Carter 1974:202). So few of even our best speculations can be buttressed with absolute proof; so many of our phenomena are inherently ambiguous. Perhaps Kroeber points the way with his notion of "necessary proof" for independent development as well as diffusion - an equal burden on both camps (Sorenson 1971:225). But where is this middle ground? Where are the specifics? And how can we factor into the equation the telling comment of George Dales discussing the apparent isolation of the Indus Valley Harappan culture (contemporaneous with those of Egypt and Mesopotamia)? Said Dales, "Yet none of the great civilizations of the world originated or thrived in a cultural and economic vacuum" (Dales 1962:86). Western European civilization, after all, did not spring full blown from the simpler tribes of the area. We (proudly!) trace our cultural heritage through Rome, Greece, and the Middle East to Mesopotamia. And how numerous are the influences we have chosen not to acknowledge or simply forgotten?

The notion of some sort of statistical mode of analysis based on probability theory appears attractive. Numbers, in their finite concreteness, often seem reassuring, a reaffirmation of our quantitatively oriented Science. Mathematical models are always approximations. How close can we come in this situation? Kluckhohn was skeptical of just such probability-based models. Culture simply may not behave according to its assumptions (Emery 1976:185). Furthermore, as both Emery (1976:196) and Julian Steward (1929:493) have pointed out, there are no absolute proofs in the real world.

These exist only in closed logical systems such as mathematics. We are limited to evidence for or against the probability of a particular occurrence. This applies even to experimentally testable natural phenomena. (Experimental anthropology, while immensely valuable for determining whether a thing might be done or how an occurrence might have happened, cannot prove that it did or did not take place in a given way at a given time.) Statements which depend for final evaluation on the empirical observation of human activity are particularly difficult of treatment. Especially in a diachronic framework, we simply can never know when all cases have been counted. We are forced to work with an open-ended data set (Blalock 1960:630).

The development of finite schemes is further hampered by the very real possibility of researcher bias (unintentional, let us assume). Data that tend to contradict one's hypotheses may be given lesser weight. One may simply fail to consider all possible explanations of a given phenomenon. The very classification of one's data may result in bias or loss of nuance. It may also be said that causality in human activity is not completely knowable, especially long after the fact (Emery 1976:199-200). Attempts have been made to build a probability-based model to distinguish historical from functional causality (Emery 1976). This would effectively separate diffusion from independent invention. In one case, two-by-two tables using "necessity" and "sufficiency" as the variables and Q-coefficient analysis were applied. While this scheme can be used to evaluate causality in a logical consistent way, it does not at all permit the separation of historical from functional explanations. The Q-coefficient alone is probably not the best mode for this analysis

(Driver 1961:326-327). Thus this judgment rests, once again, on the postulate used to set up the trial, i.e. what we choose to accept as our standards against which the data of a specific case will be measured. We are thrown back on our old attempts to juggle factors such as distance, time, formal resemblance, clustering, etc.

Another attempt to explore the logic of the diffusion-invention controversy was that of Steward (1929). His modest discussion correctly identifies "common sense logic" as a standard (and often sufficient) method for handling data in this realm. He cites spatial proximity, trait uniqueness, and possible common ancestry as the three main factors to be considered. And he rightly states that each of these must be evaluated independently, criticizing those who make one "depend upon another in an illogical manner." Steward maintains that given an identical trait in two areas, the probability of independent invention varies directly with communication difficulty, directly with trait uniqueness, and inversely with the probability of the cultures having common ancestry.

There is no problem with the first of these. But Steward's discussion using inverted speech (saying the opposite of what one means in certain culturally delineated situations) in Australia and the Americas as an example, clearly shows that the relationship should be inverse rather than direct in the second category. That is, the more a given trait from one culture resembles a trait in another culture, the less likely it is to be invented and the more likely that the multiple occurrence results from diffusion. From a logical standpoint, trait uniqueness must, it is true, be determined without reference to distribution to avoid begging the question of the one or

the other. But no objective criteria are offered and one wonders how this determination might be made except empirically. Some scheme involving trait complexity and the cognitive process of invention and discovery might be devised. But such a model would itself require a level of psychological and epistemological sophistication and complexity far beyond the scope of this effort. The real world must always be the acid test. There are, of course, limits. Esquimaux will not, presumably, invent surfboards, nor Polynesians igloos. It seems that the determination of uniqueness must rest on the trait's complexity linked to a set of historico-environmental conditions whose conjunction has produced it. This is still an intuitive procedure which must be tested empirically. But what are we to conclude should we find evidence of widespread distribution of a trait we have decided should be very unique? Was it diffusion, or was the trait not so unique after all? This criterion alone (or even in conjunction with one or two others) is clearly insufficient.

Steward's third postulate, that independent invention is inversely proportional to the probability of a common source, seems, at first blush, circular. In order to avoid the tautology, we must assume he means that the two cultures, and not the two traits, share a common ancestor. This is determined by the number of traits shared by the two groups (and, presumably, other factors). Steward's principles are useful when properly stated and understood, but scanty as an analytical system. His primary contribution is to show that logically each one (and others we may use) must be applied independently, without regard for the others to avoid circular reasoning and that all we can hope for is a greater or lesser degree of probability in our

conclusions.

Thus, it appears that either side of the diffusionist-inventionist rift offers principles that can be effectively used to critique specific cases presented by the other. But these same principles fall short of constituting coherent, logical constructs in and of themselves. Indeed, there is no litmus test, applicable in every instance, that would allow a definitive conclusion of either diffusion or invention. We are continually thrown back on "common sense" as a analytical tool. Can this be all we have to examine the origins of the sidereal compass? It is clear from the preceding discussion that the theoretical underpinnings of both the diffusionist and inventionist camps often differ in emphasis and interpretation rather than in substance. For example, does the use of similar incised-line decoration on Japanese (Jomon) and Ecuadorian (Valdivia) pottery constitute a stylistic parallel or not (Muller 1971:71)? Such questions must be answered before one can even begin to attack the problem of diffusion versus invention.

How, then, to proceed? The task is simplified by our focus on one particular trait: the sidereal compass. We can narrow the scope of the investigation by concentrating primarily on evidence pertinent to this construct. We have, therefore already achieved a sufficient degree of specificity. The compass is unusual enough and complex enough to be immediately and unmistakably recognizable. Questions of style do not enter the picture, except as auxiliary determinants. But the criterion of arbitrariness is not met. Since the compass is highly functional, great care is required when postulating links between navigating cultures with similar needs likely to engender

similar responses. On the other hand, this same specificity of focus increases the difficulty of proving the case conclusively, especially the diffusionist interpretation. This because it is often possible to build a highly suggestive argument based on multiple parallels without being able to trace the development of any one item.

Other factors, therefore, must be considered. Strong evidence for diffusion will have to exhibit additional characteristics:

- 1) Traits must be specific enough to avoid widespread distribution born of human nature.
- 2) Traits must be arbitrary, i.e. not likely to have resulted from some functional need common to all cultures.
- 3) Similar traits should exhibit such strong resemblance as to eliminate debate over stylistic ambiguity.
- 4) Distance per se will not eliminate the possibility of diffusion but mode of transport, routes, and environmental factors of such journeys, as well as concrete evidence of contact will be scrutinized.
- 5) Relative time depth should be a key factor for determining place of origin. However, in the case of non-literate cultures and a trait that today is not represented in any concrete form, this element of the analysis must assume a highly speculative and inferential character.
- 6) The existence of a developmental sequence would, likewise, be a powerful analytic tool had we reasonable assurance of the existence of past representations. Alas, this is not the case.
- 7) Each culture exhibiting the compass must be carefully examined for the presence of a trait cluster, a matrix of which the compass may

be part. Parallel clusters will be accepted as strong evidence of diffusion, the notion of complex demand notwithstanding.

Conversely, a conclusion of independent invention will be mandated by the demonstration of insufficient resemblances, physical or temporal impossibility of contact, the presence of parallel developmental sequences unlikely to have been produced by serial contact, and the absence of supportive evidence in the form of trait clusters.

The tenets of intellectual rigor demand a re-emphasis of Kroeber's admonition against the a priori assumption of either diffusion or independent invention. Either case requires the proof (insofar as we are able to demonstrate it) of an unprejudiced amassing of evidence. Methodologically, however, we will assume at the outset that the various star compasses are unrelated. This is purely a matter of convenience. The scantiness of the data in general and the consideration of an intangible element in a non-literate culture give this approach the advantage of presenting the strongest possible case for each side of the question without unfair reliance on only negative evidence. Because of the nature of the data, a strictly "balanced" approach would unduly emphasize its inconclusive character, obscuring the opportunity to reach at least a probabilistic conclusion. The assumption of diffusion would cause disproportionate recourse to negative evidence (itself so often inconclusive) to support the inventionist position. The universal nature of key elements of human character and its implications for cultural parallels are acknowledged, but only as they apply to general cultural features. This does not constitute sufficient proof or even likelihood of independent invention. On the other hand, while the passing of

culture from one generation to the next is a powerfully conservative process underscoring a pan-human resistance to change, people are clearly innovative and capable, at all levels of development, of quantum leaps of imagination and invention. A single instance of invention and subsequent diffusion is not necessarily the most plausible explanation for parallels merely because it appears to be the most economical or elegant in the mind of the researcher.

Before launching into the data themselves, a brief glance at the nature of the various types of evidence we will examine is in order. This will help us evaluate the relative importance of each category and understand the limitations of our information. The broken nature of the archaeological record throughout the Indo-Pacific region has already been mentioned. While the situation is not nearly so hopeless as some would have had us believe several years ago, the gaps are still a formidable barrier to tracing the path of human movement in the remote past. As one observer has noted, "The reconstruction of aboriginal maritime trade patterns in the Pacific Ocean is a challenging and significant, but extremely difficult task. Indeed the full extent of trade will never be known because of the lack of written native accounts and the perishability of archaeological material such as wooden watercraft" (Nelson 1961:18). Though our province is broader than that of trade alone, the caveat still applies. Not only is the record spotty, but its testimony sometimes contradicts conclusions drawn from evidence of different provenance. For example, in tracing the movements of the seafaring people who would become today's Polynesians, archaeology would suggest a relatively rapid spread from Indonesia into the eastern Pacific

between 2000 B.C. and 1000 B.C. However, linguistic reconstructions hint at a Melanesian origin around 3000 B.C. for modern Polynesian (Bellwood 1979a:423). Interpretation, as opposed to dating, is another problem facing examiners of the archaeological record. It is often "solved" by means of ethnographic analogy, despite pitfalls which might render such comparisons misleading (Orme 1974). Here, the task is reconstructing more than understanding past events. And the same techniques of re-creation by examining the present-day lives of the cultural heritors of peoples past apply. We must be attuned to that which may have been added to the navigational practices of ancient times, especially through recent contacts and aware, too, that much may have been lost.

Linguistic parallels constitute excellent evidence of influence or contact (Jett 1971:35; Emery 1976:190). Such data are arbitrary and specific and are frequently available even without benefit of written or archaeological records. They will be investigated both within and between the various cultural spheres considered.

Biological evidence, especially domesticates, will also be studied. Though there is still often sharp disagreement on the source, mode, or timing of plant and animal movements (witness the coconut and sweet potato in the Indo-Pacific region), faunal and floral distribution can offer valuable information about human movements. Biological entities cannot be reinvented or modified to the same extent as other artifacts (Carter 1974:202; Sauer 1971). While such evidence is weak as proof of a negative proposition, it can conceivably clinch a case for contact when properly supported.

Unfortunately, our information is thin in this realm.

Ethnography and history provide the bulk of our material. Exploring the possibility of connections among the various known examples of sidereal compasses, we will examine certain arguments for considering Oceania a cultural unit (Clark and Terrell 1978:298). Many have described the similarities and differences among Melanesians, Micronesians, and Polynesians and delved into the ultimate origins of the Austronesian speakers (Shutler and Shutler 1975:48). It remains to be seen, however, whether one may agree with Arutiunov's (1966:26) description of the Pacific as "the interior sea of Ameraustrolasia." In bringing to bear evidence from cultures scattered across many thousands of kilometers spanning two oceans, we face the twin problems of a plethora of cultural complexity linked to a dearth of hard data pertinent to our search. Speaking of just one piece of the puzzle, it has been said, "Cultures have been so crowded into Indonesia at various times, and so many internal movements have taken place, that a disentangling of the chronological sequence of the cultures is a very difficult undertaking" (Haddon 1920:120). While the broad picture we must examine is not quite so confusing as the particular case of Indonesia, this island-studded region is a geographic and cultural pivot point for the vast span of the star compass's distribution. The challenge of deciphering cultural relationships in this area can be seen as an intensified microcosm of our overall task.

Evidence of an astronomical nature will also be considered. It has been suggested (Doran 1983:personal communication) that clues to the origin of the Micronesian compass might be generated by

calculating the positions of the pertinent stars at various times in the remote past. Their rising and setting azimuths from different latitudes could then be compared to similar calculations from other compass locales. We have reliable information on star names from several sources, historical and ethnographic. These will be used as cultural traits to be compared as well as raw data for the calculations. In addition, we will examine the notion that the precessional motion which produces the changes in stars' positions has broader, worldwide cultural implications as a source of cosmogony and myth in general.

Another problem related to the scarcity of archaeological evidence and the inapplicability of much of the ethnographic data, is the shallow depth of written history in the Pacific area. Though earlier Chinese, Indian, and Arab sources will be used, only the arrival of Europeans produced a voluminous written record. As a result, most Oceanic historical reconstructions are based on oral tradition and myth. It is well known that members of non-literate societies can often perform "miraculous" feats of memory (such as reciting geneologies) aided by chants, legends, and other mnemonics. But there is always the question of how accurate these memories are in Western historical terms. Despite these doubts, this information is of paramount importance. It is often the only way to get inside the minds and cultures of many peoples. And, as far as possible, the same rigors of historical criticism with respect to source validity must be applied to oral accounts (Evans-Pritchard 1961:5).

The widespread repetition of astronomical and navigational lore in Polynesia has been seen as confirmation of its practical

CHAPTER IV

ASTRONOMICAL EVALUATION

The first category of evidence to be examined is the astronomical. Its multifaceted nature makes its separation into a distinct chapter somewhat artificial. Nonetheless, its centrality to the entire subject justifies this otherwise arbitrary division. Opening this chapter is an amplification of certain points broached in the discussion of temperate versus tropical observational astronomy. A few words on pertinent terminology are also included. Following is an explanation of the results of the calculations performed to discover the positions of stars and constellations from the various compasses at specific times in the past. These experimental data will serve in an attempt to determine the original location(s) of the appearance of the sidereal compass. In addition, star names and their uses in linguistic, navigational, and calendrical systems in the cultures under consideration will constitute a body of ethnoastronomical material to be used as a comparative tool for establishing or disproving links among the groups.

Star compass, star path, and other indigenous systems of navigation are based on naked-eye observational astronomy. This consists, in simplest form, of noting the apparent motion of celestial objects. Apparent motion because it is primarily the orientation and movement of the earth which produce the changes in the sky over the course of a day, a season, a year, or a millennium

called the ecliptic pole, describing a cone, as the earth itself spins around the axis. This results in the axis pointing in a constantly changing direction over the course of a 26,000-year cycle. Currently it aligns with Polaris. But 4500 years ago it pointed toward Thuban in the constellation Draco. The Egyptians aligned central shafts in the pyramids toward Thuban. Deneb will be the pole star in A.D. 10,000 and Vega 4,000 years after that. Though much brighter than today's Polaris, these stars will be farther from the celestial pole. There is no southern Polaris in our era. But a line from Hadar (part of the Centaur) to Achernar (in Eridanus) runs through the south celestial pole. And the constellation Crux (the Southern Cross) indicates its location when in the upright position (Jastrow and Thompson 1972:I-5; Kyselka and Lanterman 1976:126-127). By altering the relative positions of the stars, these changes, though too gradual to be noticed within a single lifetime, necessitated alterations in the application of astronomy over the course of centuries and enable us to date certain ancient descriptions of the sky. Other movements of earth, sun, stars, and galaxy, while important in and of themselves, do not produce changes detectable to the naked eye over the time span under consideration.

Astronomers locate stars in space by imagining the vault of the sky as a fixed dome called the celestial sphere, a practical system used by the ancients and in our own description in Chapter II. The stars move across the dome and can be positioned according to a system of coordinates akin to terrestrial latitude and longitude. The celestial equator is simply the projection of the

that have long fascinated human observers. Around 2000 B.C. Babylonian astronomers were familiar with solar, stellar, and planetary "motion." They also used a lunar calendar (Pannekoek 1961:28-35). Needham (1959:171) called the Chinese "the most persistent and accurate observers of celestial phenomena anywhere in the world before the Arabs." In a provocative note from 1724, Père Joseph François Lafitau, after five years among the Iroquois, refers to their use of a "star compass" for orientation (Gatty 1958:109). Without implying links to any of our seafaring cultures, it would indeed be fascinating to further explore such an occurrence!

What, then, are the causes of these celestial phenomena that so intrigued the ancients? It is the diurnal rotation of the earth on its axis, of course, that produces the apparent movement of the sun and the stars through the sky from the east to the west. In addition, as the earth revolves around the sun, the night sky changes since an earthbound observer looks in a slightly different direction each evening. The axis of the earth's rotation is tilted at an angle of about 66.5° to the orbital plane. This causes the rising and setting points of the sun to move up and down the horizon as the seasons progress, touching the solstitial points in June and December and passing through the equinoctial points in March and September. The tilt also alters the sun's height in the sky as the months roll by (Jastrow and Thompson 1972:I-4 - I-5).

Other motions also affect the appearance of the heavens. The most important of these for our purposes is the change in orientation of the earth's axis known as precession. Affected by the moon's gravity, the axis revolves very slowly about what is

Thus, we face the task of synthesizing these sometimes overlapping, sometimes contradictory views of the roles of oral history and myth (and how the two might be separated) in cultural formation and reproduction. The succeeding chapters will use the analytical framework sketched above to evaluate the limited and often divergent data to be presented in hopes of at least summarizing the present state of our knowledge on the possible origins of the Carolinian sidereal compass.

validity (Johnson and Mahelona 1975:viii). These common traditions spread over a vast portion of the Pacific may, however, reflect only the common origin of its inhabitants and not the efficacy of the teachings. David Lewis (1978b:150) maintains that unlike other legends, navigational lore is transmitted word for word because the life-and-death nature of its worth is more important than the psycho-social self-image implications of other cultural traditions. Unfortunately, Lewis weakens his own argument by stating on the same page that all legends are "invariably repeated word for word" lest the teller risk the immediate protests of the listeners.

It has also been said that the myth-history dichotomy is not one of "fantasy" versus "truth," but rather of two distinct interpretive frameworks. Legends, even when set in an explicit historical context, are symbolic and allegorical rather than factually narrative. And the recounters of such tales know very well the difference between legendary and historical events (Evans-Pritchard 1961:8). This symbolic nature of myth was also stressed by de Santillana and von Dechend (1969:48) who saw it as representing the "general order of things," an eternal, cyclical cosmos rather than actual historical events. They, too, attribute great sophistication to our long-gone ancestors, especially in the realm of plotting and using heavenly motion to generate cosmic allegory (1969:71, 327). Their work traces common themes through the legends of cultures as disparate as the Norse, the Polynesians, and indigenous North Americans. Sahlins (1981:14), too, sees the events of myth as constituting "archetypical situations" which punctuate a culture's understanding of its own history and destiny.

terrestrial equator on the celestial sphere. Celestial latitude, called Declination (Dec.), is measured in degrees and minutes north or south of the equator. These are designated as positive and negative values, respectively. Celestial longitude is defined somewhat differently. Because terrestrial meridians of longitude spin with the earth's rotation, they cannot be projected to fixed positions on the celestial sphere. Instead, by common agreement, celestial longitude is measured from a point determined by the intersection of the equatorial plane of the earth and the plane of its orbit. This is the vernal equinox, currently marked by a star in the constellation Aries. Because of precession, this point changes in relation to the stars (Jastrow and Thompson 1972:I-18 - I-19). But celestial longitude is most commonly designated by Right Ascension (R.A.), a temporal measure based on the equivalence of 360° of longitude and 24 sidereal hours. It is measured in hours and minutes east from the vernal equinox. For example, a star found 60° east of the zero point has a Right Ascension of four hours. Since the sidereal day, the period of the earth's rotation, is approximately 23 hours, 56 minutes, stars rise four minutes earlier each 24-hour day as computed by solar clock time (Jastrow and Thompson 1972:I-21 - I-23).

The earth's motion is not the only factor affecting the development of an observational astronomy and its application to practical problem-solving. As was discussed in Chapter II, the type of system likely to be invented is influenced by the observer's location on the earth's surface, especially by the latitude. These essential differences were recognized by de Saussure, an early

student of Arab navigation (1928:95). But Aveni (1981:62), while correctly noting the sidereal compass and linear constellations (star paths) as unique astronomical contributions of Oceania, fails to mention the Arab compass. Its existence at the very edge of the tropics remains problematic for his temperate-tropic dichotomy.

Star paths have been referred to as linear constellations. While this may be a useful designation for us, there is no indication that the practitioners of star compass navigation thought of their individual star paths in this way. It is clear, however, that they identified and used so-called "cluster" constellations, the type familiar to us and cultures the world over. Kursh and Kreps (1974:335) maintain that star paths of both northern and southern hemispheres are rarely found together in a given navigating culture. And if present, they say, such stars would never be equidistant from the equator. They contend that northern horizon stars, for example, allow northward voyaging when aligned with a canoe's bow and provide southern courses with stern alignment. But the sidereal compass itself belies this argument: both northern and southern stars are used, often with Declinations of similar magnitude but opposite sign. Further, no account is taken of changing star Declinations due to precession. This may hide correspondences of the past. Star compass aside, current work (e.g. D. Lewis, Gladwin) indicates that star paths are chosen on the basis of courses to specific destinations rather than a set of standard directions. The compass is simply a refinement and organization of these techniques (D. Lewis 1978b:75).

The immediate task before us, then, is to examine the

various sidereal compasses in order to determine, purely on the basis of the internal astronomical evidence, whether they can be linked temporally and geographically. A comparison of the particular stars used in each one might indicate that they were all developed at about the same time and/or in the same locale. Similarly, anomalies or inconsistencies appearing in any or all the compasses might be resolved by the assumption of common ancestry based on a celestial configuration of a particular time and place.

Several investigators have speculated on the possibility of discovering the origins of both the Arab and Carolinian compasses on the basis of astronomical data alone. D. Lewis (1978a:62) suggests common origins when he calls the "error" of both in taking the azimuth of Altair for due east a "significant correspondence." That star actually rises about eight degrees north of east. A parallel situation exists in Kiribati, a north-south chain straddling the equator. Local astronomy uses Rigel to mark the celestial equator. This star, one of the feet of Orion, actually lies in about Dec. -8° . In equatorial latitudes the celestial equator passes through the zenith. Only stars of Dec. 0° or thereabouts follow such a course. Thus, Rigel passes well south of Kiribati. This could be interpreted as meaning that this astronomical system originated to the south (D. Lewis 1974:140, 144).

In the case of the Arab compass, its Indian Ocean origin seems clear since some of the stars included are either invisible or too high to serve as directional indicators in the Mediterranean (Tibbetts 1971:295). In fact, in the Mediterranean the stars of the Dipper do not rise and set at all but circle Polaris remaining

always above the horizon (de Saussure 1928:102-103). On the other hand, it appears to be of more northerly derivation than the Carolinian version since Canopus (Suhail in Arabic) rather than the Southern Cross gives its name to the south pole (D. Lewis 1978a:62). This argument is weakened considerably, however, by the fact that today Canopus is of only slightly more northerly Declination than Crux. As recently as A.D. 1000, Canopus was at about the same distance from the equator as the prominent stars of the Southern Cross. One thousand years ago Gamma Crucis (by convention, stars of any constellation are designated by letters of the Greek alphabet in descending order of brightness) had a Declination of -51.5° while Canopus was at -52.4° . In ancient times, this difference was much greater. From the southern edge of the Mediterranean, both stars were visible, but so low on the horizon as to make either inconvenient for navigation.

Lewis also claims that many of the southern quadrant stars named in the Muhit are uncertain. But this is contradicted by Tibbetts (1971:296) who maintains that their names are "well known." However, he despairs of ever dating the compass by analyzing how precessional change has affected the azimuths (Tibbetts 1971:295). This same opinion was previously offered by de Saussure (1928:103) who stressed the impossibility of determining the precise geographic origin of the compass since the azimuths change with the latitude of the observer. Thus, as a vessel moves north or south, the bearings indicated by a rising or setting star change as well.

Both scholars note that Ibn Majid stressed the approximate nature of the rhumb designations on the compass (Tibbetts 1971:297-

298; de Saussure 1928:104n.2). De Saussure (1928:113) attributes the anomalous positions of the two azimuths associated with various stars of the constellation Scorpius to a convention adopted after the introduction of the magnetic compass. He notes that the stars in question form two houses of the Arab lunar zodiac (shared as well by the Chinese and Hindu zodiacs!). These names were presumably borrowed and assigned to the rhumbs they now designate. De Saussure draws a parallel between such a convention and our own retention of the name of September, though it no longer indicates the seventh month of the year (1926:117). But if the parallel is to be a faithful one, it should imply a time in the past when the stars used in fact held positions in a true sidereal compass rather than simply denoting the rhumbs of a magnetic rose. In his concluding remarks de Saussure (1928:124), following Prinsep (1836:788), in fact affirms his conviction that the Arab rose dates to remote times before the magnetic compass despite the then-common wisdom linking it to the modern instrument.

However valuable the clarifications of detail and analyses of these researchers, they fail to deal with a point of paramount importance. It is clear from their work and that of others (e.g. Ferrand 1928) that by the time of Majid, star names rather than the actual azimuths were the outstanding feature of the Arab rose, though the stars themselves were still important directional indicators for navigation. But if the sidereal rose was once a functional element of Arab navigation, then the distribution of its azimuths must have corresponded to the actual rising and setting points of the stars used. We have only to look at the Carolinian

compass, still in use today, to confirm the logic of this position. It is not, of course, important that the Declinations or azimuths of the rose can never be made to correspond to the actual number of degrees of the magnetic rhumb indicated. The two systems are essentially too different for such congruence. What is necessary is an internal consistency which will permit the sidereal system to operate with sufficient accuracy to permit successful navigation among the locales visited by its users. Thus, de Saussure's failure to precisely fit star bearings to magnetic rhumbs is irrelevant.

Majid's insistence that rhumbs were only approximate indicators was certainly accurate for his day. But Tibbetts (1971:297) surely errs when he dismisses the significance of the inversion of the azimuths of Alpha/Beta Centauri (al-Himaran) and Canopus (Suhail). The Centaur is currently at a Declination of about -60° while Canopus is only -52° in spite of its more southerly position on the Arab rose. For an observer at 20° N Lat. this constitutes a bearing difference of about 11° , or nearly a full point in the traditional Western mariners' compass. This is clearly an error of unacceptable magnitude for the practical navigator. The same inversion exists in the positions of the Pleiades (al-Thurayya) and Arcturus (al-Simak). The Pleiades are now farther north, whereas once they were to the south of Arcturus.

Is there a better way to resolve these anomalies of relative position? We have calculated the precessional changes in celestial coordinates of the stars used in the various compasses (see the Appendix for a brief description of these calculations). As recently as 1000 year ago, Arcturus rose several degrees north of

the Pleiades. Going back another 500 years finds this difference augmented to about 11° . As one recedes even farther into the past, the gap increases at least until about 3500 B.C., the limit of our calculations. The Alpha/Beta Centauri - Canopus relationship displays a similar pattern. Sometime between 1500 and 2000 years ago, their relative positions changed, reflecting those of the Arab rose. In about 500 B.C. the difference in azimuths was on the order of 5° . Five hundred years earlier the separation approached 10° . Around the time of Christ, in fact, all the stars in question were as they are depicted (relative positions only!) in the representations we have of the Arab sidereal rose. Several hundred years earlier or later, this was not the case.

There is, however, a complicating factor. Some of the differences between two adjacent bearings are very small, on the order of a degree or two (e.g. Capella and Vega). The problem arises, then, of explaining why a navigator would choose two azimuths in such close proximity. There is no definitive answer. However, one need only look again to the Carolinian compass, a functioning example, for instruction. Here, the azimuths denoted by Tarazed (Gamma Aquila) and Altair, the two closest of the entire compass, show a difference of barely 2° in their rising points along the horizon from the approximate latitude of the Carolines chain. We have already seen how the compass points are bunched around the east-west line, presumably to serve the local needs of the navigators. A similar explanation in the Arab case is, indeed, plausible, though less readily understandable in light of the scanty information and long, open-water sea routes of the Indian Ocean.

Interestingly, it was also just over 2000 years ago that the stars now used in the Carolinian compass took on their current relative configuration. Prior to that time the positions of Gamma Corvi and Orion's Belt were reversed. This hypothetical compass (Fig. 8) shows roughly the same distribution of stars as that used today in Micronesia, a disproportionate number falling close to the east-west line. It is true that points one and two, as well as 11 and 12, seem unusually close together. But it should be remembered that in today's compass, the three stars of the constellation Aquila are separated by a comparably small amount. In addition to this temporal coincidence, it should be noted once again that the Arab and Carolinian roses share nine specific stars including Polaris, yielding 18 of 32 azimuths in common: one each for the north and south poles plus two (a rising and setting point) for each of the other eight stars. Another parallel between the two systems is the assumption of east as the cardinal direction and the designation of Altair to mark this point.

These similarities warrant closer scrutiny since, on the surface at least, they suggest common roots for the two systems. The shared emphasis on the primacy of the east is not particularly troublesome. The rising sun has engaged the human mind for millennia and is a common cultural referent around the globe. Our own language preserves this thread in the verb "to orient."

The choice of Altair is more complicated. Only a body of Dec. 0° , i.e. on the celestial equator, will appear to rise due east and set due west. This is true regardless of the observer's latitude. An example would be the sun at the equinoxes, usually

Setting

Rising

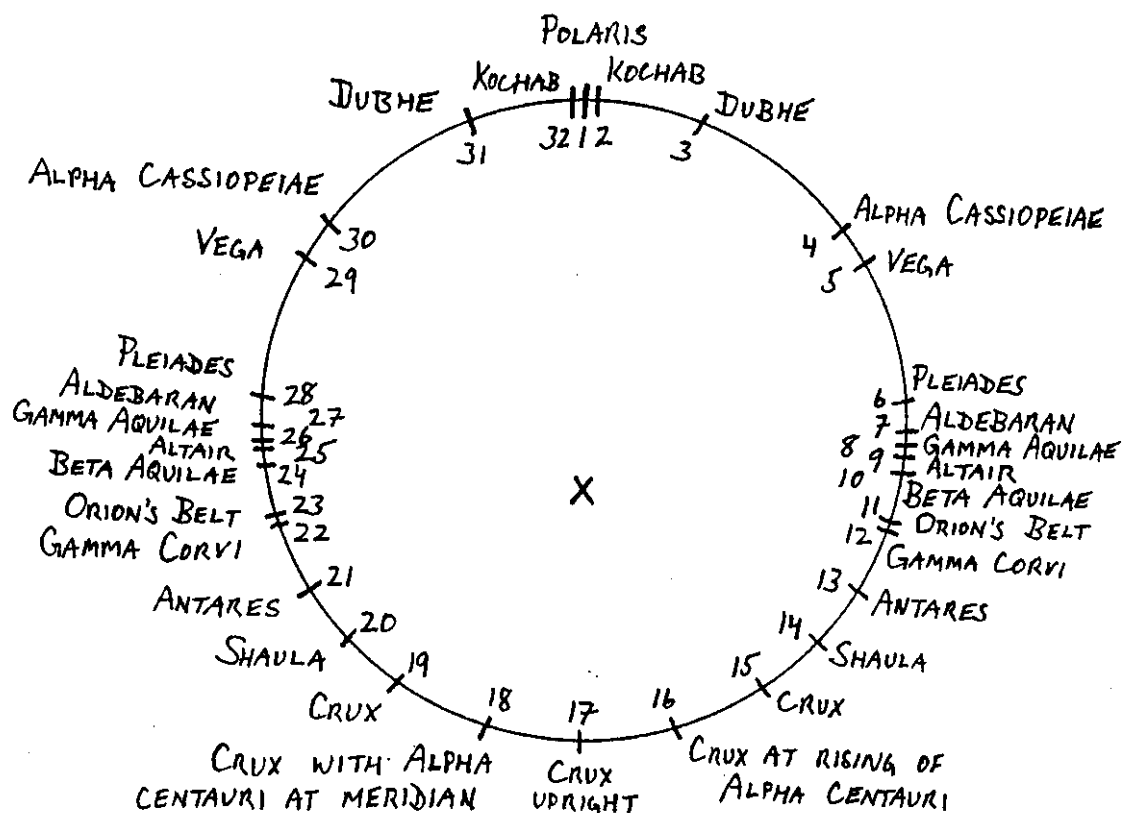


Figure 8. Stars of the Carolinian sidereal compass as they appeared about 2000 years ago. The "X" marks the actual astronomical center of the azimuths.

March 21 and September 21. It has been suggested (Doran 1983:personal communication) that Altair might, at some time in the past, have occupied such a position due to precessional changes. But at no time during the last 6000 years was this the case. Altair, whose current Declination is $+8.8^{\circ}$, was never closer to the equator than 2000 years ago when it appeared at $+5.8^{\circ}$. This same period saw two very bright stars, Spica in Virgo and Bellatrix in Orion, flanking the celestial equator barely more than 1° off the line. Why were these prominent celestial objects not included in the scheme if the compass indeed originated at that time? One explanation could be that 2000 years ago they were not as bright as they are today, though no evidence to this effect could be found. In any event, Altair is brighter than either of the other two. And, it must be remembered that magnitude is often not the deciding factor in the choice of compass stars.

There is another, more plausible, explanation. During the last 5000 years the Declination of Altair has varied between $+5.8^{\circ}$ and $+10.2^{\circ}$. It can be seen from Figure 1 that the Carolines fall mainly between the latitudes of 6°N and 10°N . Thus, for five millennia Altair has passed through or very close to the Carolinian zenith on its diurnal trip across the sky. The importance of the zenith star concept for fixing latitude in Polynesian navigation has already been mentioned. It seems possible that such use of zenith stars was similarly made in the Carolines but has since been forgotten. In 1866 a Captain Sanchez y Zayas referred to a water-filled cane used to observe the zenith by a navigator from Elato in the Carolines who had arrived at Tinian in the Marianas (D. Lewis

1978b:78; Åkerblom 1968:112-113). Unfortunately, the use of such a device remains obscure; it could also have served in the determination of the altitude of Polaris on the long voyage to the north. The absence of the zenith star concept among today's Carolinian navigators was confirmed by Thomas (1983:personal communication) who currently works among them on Puluwat. Nonetheless, Goodenough (1953:5), Åkerblom (1968:103), and Gladwin (1970:154) all conclude (assume?) that Altair designates due east and is the pivotal point of the compass because it passes almost directly over the Carolines.

Despite the absence of explicit reference to zenith stars in the Carolines, navigators there refer to bands or paths, jaan, followed by stars of equal Declination (Goodenough 1953:4). As in Hawaii, such stars are said to "travel the same road" (Gladwin 1970:148). Procyon in Canis Minor and Bellatrix, bright stars of similar Declination but vastly different Right Ascension, are counted among the companion stars to Altair used for navigation when the latter is invisible (Gladwin 1970:154). Clearly, then, the concept of latitude/Declination is strong in Carolinian navigation, pointing to the likelihood that Altair's position as zenith star and not its proximity to the celestial equator was the deciding factor in its choice as the keystone of the Micronesian sidereal rose.

Both what of the Arab compass? Altair appears to rise even farther from true east, though only marginally, from the slightly higher latitudes frequented by Arab seafarers. Here too, then, it could not have been chosen because of some past correspondence with the celestial equator. Complicating the puzzle is the fact that in the late fifteenth century Ibn Majid stated that the easternmost star

of Orion's belt, Alnitak, marked due east because it was separated from the pole by 90° (Grosset-Grange 1972c:39). Though this is not quite accurate mathematically, it was certainly closer than Altair. Majid's sixteenth-century translator, Admiral Sidi Ali Çelebi, was aware of changes in star positions due to precession (Ferrand 1919:500-501). Tibbetts (1971:150) maintains that while the "ancients" were aware of Altair's position north of true east, early mariners used it anyway because their measurements were only approximate and because "the seamen of the Indian Ocean and others relied on it and so described it to each other."

Prinsep (1838:774-778) analyzes the compass star names and Declinations given in the Muhit, concluding that it must have its origin around A.D. 1282. He suggests Loheia (15° N Lat.) in the Red Sea, the starting point for all the voyages to India described in the Muhit, as a likely locale. From this latitude most of the stars "...can be made to rise and fall in their assigned positions on the horizon." He is troubled, however, that no single latitude is sufficient to explain the distribution of the azimuths. But his arguments reveal certain weaknesses. His interpretations of some of the Arabic star names do not accord with the later lists of Ferrand (de Saussure 1928:92n.1) or Tibbetts (1971:296n.133). He resolves the translation difficulties by choosing stars which fit his overall analysis. By so doing, he eliminates completely the inverted pairs Arcturus-Pleiades and Canopus-Centaur. He also fails to deal with the problem of Altair as indicator of due east. His statement that the star names of the rhumbs were purely conventions circumvents rather than furnishes an explanation. It is much more logical to assume that

while the rhumb names may well have been conventional by the time of Majid, they were not always so. Earlier Arab navigators, heritors of both the magnetic and sidereal compass traditions, combined the two, much as the Carolinian navigators are doing today (Gladwin 1970:155-156; Thomas 1983:personal communication; Alkire 1970:41-43). The Declinations given by Majid were probably recent additions born of the Arabs' own instrumental astronomy (Prinsep 1836:784-794).

An examination of the Right Ascension of the stars in both the Carolinian and Arab compasses reveals gaps, sometimes large. Though the rising times are generally spread out over the course of a given 24-hour period, the current distribution in the Carolinian compass contains two breaks of approximately five hours each. In the midst of the voyaging season, one of these gaps appears between 2 a.m. and 7 a.m., while the other stretches from 4 p.m. until 9 p.m. During these times no compass stars rise, though others would be visible farther along their paths during hours of darkness. One should not attach too much importance to these gaps since, as we have seen, companion stars, those of similar Declination but different Right Ascension, would normally be used when compass stars themselves were invisible. However, a computation of Right Ascension and rising time for these stars 2000 years ago reveals, in the case of each compass, one large gap of 12.5 to 13.5 hours! In the case of the Midsummer Carolinian compass, this falls almost entirely in the daylight hours (4 a.m. - 5 p.m.). While we have seen that such an arrangement is not essential to the efficient functioning of the system, it would certainly be an added convenience.

Since the Arab compass uses so many of the same stars, the gap

falls in virtually the same place in their rising progression. However, as the monsoon conditions of the Indian Ocean necessitated a different sailing season, the gap does not correspond to the daylight hours. The winter Northeast monsoon traditionally carried Arab voyagers to India. At this time of year, the gap spans the entire night. This could be an anomalous carry-over from a system developed elsewhere. At first blush, this seems terribly inconvenient for monsoon-dependent voyaging. Several additional facts must be considered, however. Arab sailing extended well into the spring, the seas being "closed" only for about three months between June and September. In the vicinity of Indonesia and other island groups, wind patterns can differ considerably, altering the favorable time for local seafaring. There was also more sailing on the wind than is sometimes supposed and the offshore-onshore pattern of coastal winds allowed more temporal flexibility. Finally, "typical" monsoon conditions do not manifest themselves in all parts of the ocean at precisely the same moment (Grosset-Grange 1970:236-238, 1978:18, Fig. 6). All these factors, combined with the use of companion stars, should have permitted effective use of a borrowed system regardless of the time of appearance of the compass stars themselves. Of course, other interpretations are possible. The compass may, in fact, date from different epochs in Arab and Oceanic waters.

How, then, to explain the choice of Altair and other anomalies of the Arab rose? On purely astronomical evidence, the arrangement of Arab star azimuths seems to date to about the beginning of the Christian era. The relative abundance of azimuths near the north pole and paucity of those adjacent to the south might argue in favor of a

more northerly derivation, though they could simply indicate a lack of common routes to the south. The Arabs were well-known to be adept at latitude determination, making use of a variety of instruments to measure the height of Polaris and circumpolar stars (Prinsep 1836:passim; Ferrand 1928:passim; de Saussure 1928:passim; Tibbetts 1971:passim; Grosset-Grange 1978:passim; Tolmacheva 1980:passim). This facility enabled them to make long east-west voyages across the Indian Ocean at least as far as the Subcontinent and also supports the theory of northern derivation. However, Tibbetts' report of the use of Altair in the Indian Ocean (cited above) implies its ocean-wide use. His "seamen of the Indian Ocean and others" could easily be navigators from or in contact with Indo-Pacific lands to the south who taught the Arabs to key their compass system to Altair. As we have seen, the astronomical requisites of navigation by rising and setting azimuths are particular to the tropic regions. This fact undercuts attempts to derive the rose from the northern reaches of the Red Sea or Persian Gulf which lie outside the tropics. Our purely astronomical examination, while unable to definitively answer the question, suggests a combination of tropical and non-tropical systems of elements borrowed from or invented in a broad range of latitudes. To further the investigation, we must take a new look at the astronomy of the sidereal rose, not simply as a system of nautical orientation but as a cultural artifact in itself.

One potentially fruitful area of examination is linguistics. It might be possible to trace the thread of compass development by delving into the etymologic origins and relationships of star names

and compass terminology. Three and possibly four of the stars in the Arab rose have names of Persian origin. Al-Gah or al-Jah (Polaris), al-Tir (Sirius), and al-Silbar (Achernar) are all Arabized Persian words (Ferrand 1924:passim). In addition, an older name for Altair, al-Hiran, is also included as a possible loan from the Gulf. Even the word for rhumb, hann, is from the Persian meaning "house." It is also interesting to note that such other Arab seafaring terminology as the words for port (bandar), ship's master (nakuda), and rutter (rahmani) all are of Persian derivation (Ferrand 1923:311, 1924:passim; Hourani 1951:65). Arab seafarers of Majid's day also used the beginning of the Persian sidereal year, Nirouz, as the base point for determining the sailing seasons, their own lunar calendar being too irregular with respect to the changing seasons (Ferrand 1924:passim; Grosset-Grange 1972a:47, 1972c:78; Tolmacheva 1980:188).

On the basis of this evidence, de Saussure (1928:95) suggests a Persian Gulf origin for the entire system which, he says, was likely used to navigate the seventh-century A.D. route to China and the second-century course to Indochina. Hourani (1951:107), however, notes that most rhumbs had Arabic names and that at least one of the Persian names, al-Gah (Polaris), had replaced even earlier Arab nomenclature, Banat na'sh. Hourani seems to be mistaken if he means to identify Polaris by this term. The third azimuth (counting from the north pole) of the Arab compass is called al-Na'sh. Earlier works identify it with Ursa Major. More specifically, the four stars of the bowl of the Big Dipper are usually indicated (de Saussure 1928:106-107), though Tibbetts (1971:296n.133) equates it with Dubhe (in the bowl) or Mizar, located in the Dipper's handle. To confuse matters a

bit more, Alkaid, at the far end of the handle, is also referred to as Benetnasch (A Map of the Heavens 1957). The important point to remember, regardless of the actual identity of Banat na'sh, is that none of these other stars ever appears very close to the celestial pole during the 26,000-year cycle of precession. In about 1000 B.C. the pole star in the north was Beta Ursae Majoris, called Kochab (from Kawkab, "the star") by the Arabs. The exclusivity of the name confirms their awareness of its unique position in the sky, just as the Persians later called Alpha Ursae Minoris, our Polaris, Gah, meaning "the place." Kochab ceased to occupy this special circumstance about 2000 years ago (Tolmacheva 1980:188; Ferrand 1924:218)!

There is no linguistic evidence linking the Arab rose with any other to the east. In a 1916 article in the Deutschen Geographischen Blattern, Ludwig Cohn claimed to have found Arab elements in Micronesian speech and Islamic influence in Yap and the New Hebrides (now Vanuatu). He therefore postulated an Arab colony on Ponape in the eastern Carolines before A.D. 900. But Tibbetts (1957:36) doubts the existence of such an early presence in the Pacific. He also notes, however, the frequent Arab use of the height of al-Murabba', the Southern Cross, for latitude determination when sailing south of the equator (Tibbetts 1971:340). This constitutes an intriguing addition to the Arab navigational repertoire, furnishing another parallel to the Carolinian system.

Astronomical similarities do exist between the Arab and Chinese systems. Measurements found in the Muhit are close to those in a work entitled Wu Pei Chieh (Needham 1971:571). But this shows

the comparable accuracy of the practitioners rather than cross-cultural borrowing, since both used the breadth of the fingers held at arm's length to measure the angular height of the pole star and others (Needham 1970:143; Prinsep 1836:passim). In fact, there was an essential difference between the Chinese azimuthal constellations and the Arab rose. The Chinese positions were found by lowering to the horizon the lunar (zodiacal) mansions rather than by observing rising and setting azimuths (Needham 1962:265). Before examining the extent and timing of Arab contacts with Asia and beyond, we must turn to the Pacific to explore questions of navigational unity and diversity among its numerous island seafarers.

It is perfectly clear from the navigational and calendrical star names from the central and western Carolines that there is sufficient uniformity throughout the area to regard the various island astronomies as one (Goodenough 1953:passim). Beyond its limits, this is not the case. Some cognates are found on Ponape and the Marshalls, fewer in Kiribati, and almost none in Melanesia and Polynesia. Nonetheless, there are, in fact, cognate names from as far as Ontong Java, a wind rose site discussed above. Other similarities, it is maintained, are no greater than would be expected from the use of any sidereal system (Goodenough 1953:2, 41; Åkerblom 1968:149).

However, recent work by Johnson and Mahelona (1975:39-62) seems to indicate closer etymologic relationships among Pacific star names. Some of these links are revealed by comparing names of months which were often designated by a prominent star associated with that season. Thus, the Micronesian Määnap (Altair) finds an echo across western and central Polynesia as some variant of manu, associated with

a constellation depicting a bird, as in Aquila, or with one of the "pillars" which hold up the sky. Other west Polynesian month names resemble the Micronesian Tumwur (December-January) which may also be linked with the Indonesian Timur (east) and Tagalog Timog (south), though these last connections are not very clear. The Micronesian constellation name Jiic or Yis (Leo) is rendered in Polynesia as Ikiiki (Hawaii), Ite (Samoa), Iti (Marquesas), and Idit or Ititi (Nukuoro), though different months are associated with them.

Another linguistic point worth mentioning is the Hawaiian term for the Southern Cross barely visible from these islands: Newenewe. This is a possible metathesis of the Micronesian Wenewene Eer, also indicating Crux (Johnson and Mahelona 1975:70). This could indicate a Carolines-Polynesia link, though it might merely reflect the common linguistic heritage of the two areas. In a similar vein, variants of the terms tokelau for north and west and tonga meaning south or east have been identified all across Polynesia and parts of Melanesia from Ontong Java to Huahine (Sarfert and Damm 1929:195; Ellis 1931:14; Åkerblom 1968:51-52; D. Lewis 1972:73-74).

The nine closely grouped stars of the Carolinian compass, stretching from Vega to Antares, can be seen as a sort of parallel to the ten Tahitian "Pillars of the Sky." Though only Aldebaran and Antares are found in both lists, the relative positions of the two sets correspond quite closely (Johnson and Mahelona 1975:62-63). D. Lewis (1972:239-240) associates these "pillars" with the zenith star concept and favorably compares the latitudes of various islands to the A.D. 1000 Declinations of some of these stars. This era is thought to be that of extensive Polynesian voyaging. It is clear, however, that

Polaris and Dubhe, the first pillars, are not found in the zenith of any land familiar to Polynesians since they are far to the north. Their inclusion in any list of navigating stars is certainly as directional indicators, as Lewis freely admits. It is perfectly possible that such a list might include both zenith and azimuthal points. But such a compilation would not support the notion of the Tahitian sidereal compass suggested by Johnson and Mahelona. A quick check of several of the A.D. 1000 rising and setting azimuths of these stars from Tahiti reveals that they could well have represented courses to neighboring groups. But since the Society Islands, where Tahiti is located, are at the hub of eastern Polynesia, almost any stars would have given comparable results. By the same token, Lewis' Declination-latitude list is suggestive, but far from conclusive. The inclusion of Polaris and Dubhe, the one not visible, the other barely so from Tahitian waters seems to indicate contact with areas and/or peoples north of the equator, though this knowledge could have come as the result of contact with Europeans.

From elsewhere in Polynesia comes more star compass evidence. In Tonga, it will be recalled from Chapter II, an elder of a traditional navigating clan pointed out eight stars denoting standard directions rather than individual islands. These, and others he had forgotten, had been taught him by his navigator father. Each bearing was also associated with a star path or kaveinga. The same method was called 'avei'a in Tahiti. As recently as ten years ago, this system of navigating between islands was still used in Tonga, though the traditional star names are no longer known. Similar evidence was recorded in nineteenth-century Huahine, near Tahiti (D. Lewis 1972:77,

1978b:75-76).

Two other phenomena already mentioned, zenith stars and wind roses, are also found throughout the Pacific. The zenith was observed in such widely separated places as Tikopia and Tonga (D. Lewis 1972:233-234, 242, 1978b:33-34, 44) in the central and western parts of the ocean as well as the eastern areas noted above. The wind compass also finds parallels in the Carolines.

In contrast, much of Melanesia is without firm evidence of long-distance voyaging. While the Trobriand Islanders, Malinowski's "argonauts," are familiar with certain stars and constellations including Orion, the Pleiades, and Crux, they do not use them for navigational purposes (Malinowski 1961:225-226). Inhabitants of the nearby Amphletts almost always sail within sight of land and, similarly, do not use their extensive astronomical knowledge for wayfinding (Lauer 1970:394).

Other nomenclature and techniques, though not as significant as a complete sidereal compass system, are suggestive because of their even broader distribution. Though Dodd (1972:47) is skeptical of the practical applications of the Carolinian compass (he did not have access to Lewis' and Gladwin's recent findings), he does describe a Polynesian navigational technique which finds a fascinating reflection in the Arab world. On east-west courses near the equator, a navigator would align the bow of the craft with a star rising over the destination and the stern on one setting over the departure point (or vice versa). In this way the voyagers could always return to their proper course should current or adverse winds throw them off (Dodd 1972:49-50). This "fore-and-aft" system is used by Ibn Majid to

describe some of his own courses; "si l'avant du navire est sur l'une (des étoiles dont traite le texte) l'arrière est sur l'autre" (Grosset-Grange 1972c:60). This could merely reflect the practicality of navigators dependent upon the stars for accurate landfalls. Nonetheless, it supports the notion of a tropical origin for the Arab rose. Another inter-ocean parallel involves the star Canopus. Found in the Arab compass and the Madurese, it was reported to Marco Polo, along with Crux, as a navigation star used by Sumatran sailors of the Indian Ocean (Taylor 1957:124).

It is difficult to draw solid conclusions from navigational data recently collected in Indonesia. Since it is scanty and uncertain, we have not tried to analyze the compass points individually as in the Arab and Carolinian cases. Nevertheless, certain features are worthy of mention. The so-called "sea nomads" of the Sunda Islands speak a language related to Malay. The term for sun is mata aloi, the first part of which, mata, means "eye" (Sopher 1965:177). This is akin to the Pacific-wide name for the Pleiades, Matariki (or some variant), meaning "little eyes" (Johnson and Mahelona 1975:16, 94).

We must not make too much of such parallels which might be attributed to the common Austonesian base of many Pacific languages. They do, however, reaffirm a thread of cultural unity, some strands of which may entwine the sidereal compass. We have made mention of the Madurese tradition of a 25-point azimuthal rose, though sailors there today can identify but a fraction of these bearings (Liechti et al. 1980). Interestingly, Ibn Majid noted general agreement among the seafaring peoples of the Indian Ocean - Arabs, people of Hormuz,

Indians of both the east and west coasts, and the Zangs of East Africa - on the use of the 32-point rose. But the Chinese and Javanese, he said, use one of only 24 stations (Ferrand 1924:216). Could the dimly remembered 25 bearings of today's Indonesians be, in reality, the 24 of Majid's fifteenth-century treatises written an ocean away?

To conclude, we must note once again the remarkable coincidence of the particular stars used in the Arab, Carolinian, and Madurese compasses. Figure 9 illustrates the overlap between any two and among all three when Polaris and a southern marker are included in the count. In the Arab-Carolinian case, this represents 18 of the 32 azimuths of the rose.

However suggestive it might be, this body of astronomical data cannot stand alone in any attempt to prove or disprove an historical relationship among the various sidereal systems. It must be buttressed by information of a broader nature so that the astronomy may be placed in a cultural context. Thus, before proceeding to a synthesis and analysis of the material, we will investigate the archaeological, ethnographic and historical records in order to describe what is known of the movement of peoples and ideas throughout the millennia of Indo-Pacific exploration and settlement.

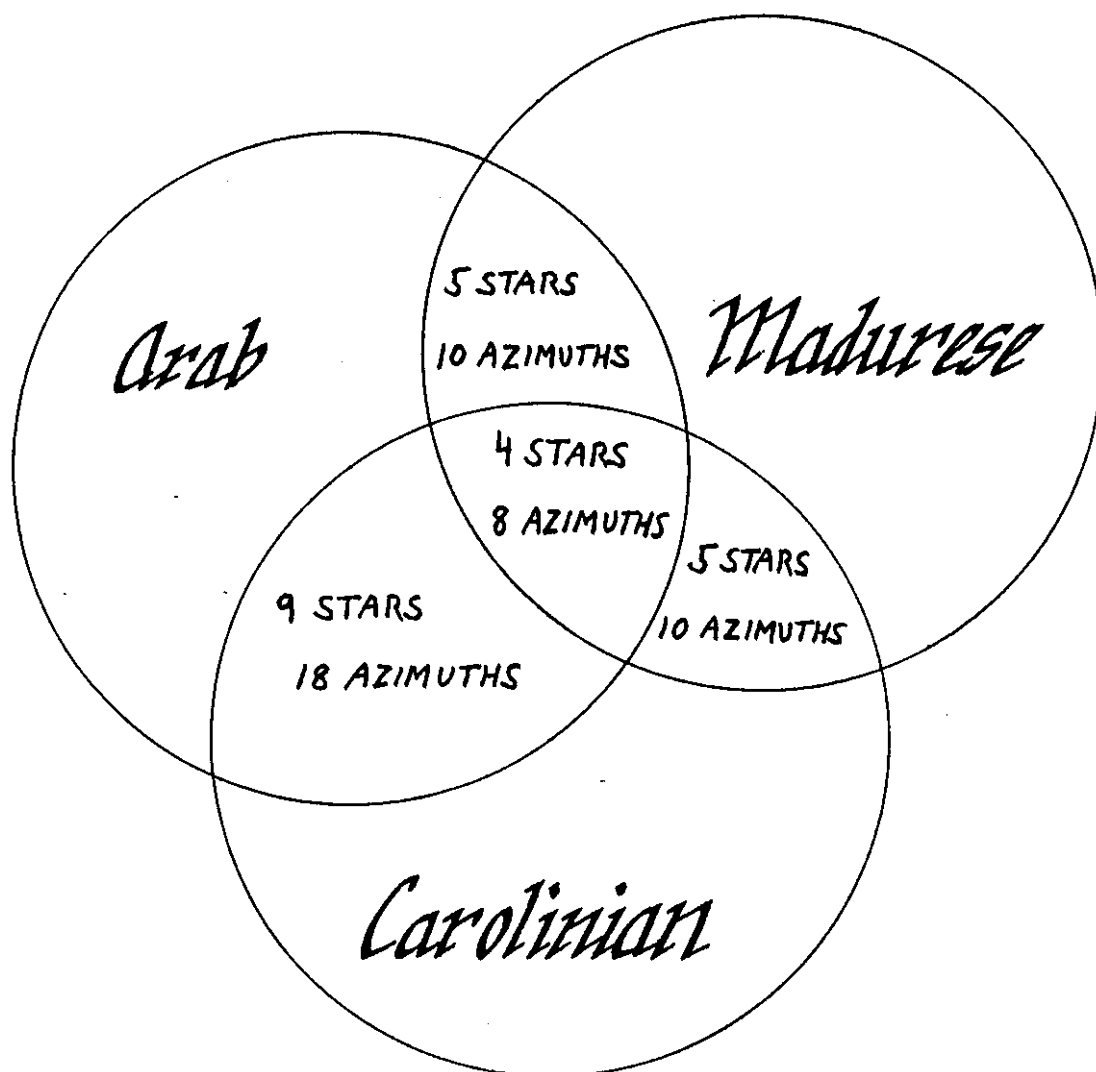


Figure 9. Points shared by three sidereal compasses.

CHAPTER V

ARCHAEOLOGY, ETHNOGRAPHY, AND HISTORY

In order to fully understand the similarities and differences among the various sidereal navigation systems of the Indo-Pacific region, it is necessary to sketch the major elements of migration and settlement patterns, especially of the Pacific islands. Only after placing the evidence already uncovered in a deeper historico-cultural context can it be properly analyzed. This will necessitate the cross-cultural comparison of specific traits in an attempt to evaluate various explanations for resemblances among the star compasses, especially between the Indian Ocean Arab compass and those of the Pacific. In addition, evidence of inter-ocean contact from the realms of archaeology and ethnography will be brought to bear on the subject.

No attempt will be made to delve into the prehistory of the truly ancient peoples of mainland south and Southeast Asia. Similarly, the origins of the earliest coastal populations of the Persian Gulf, the Arabian Peninsula, and the East African littoral are beyond the purview of this paper. In Indonesia and the Pacific the great number of islands and potential migration routes make it impossible to trace with absolute certainty the history of that area's first human inhabitants. Nonetheless, certain broad currents can be disengaged from the complexities of the situation.

The recurring episodes of Pleistocene glaciation in the northern middle latitudes led to a periodic lowering of sea level in

Indonesia. The subsequent extensions of the continental land masses linked Australia with Tasmania and New Guinea and joined the islands of Sumatra, Java, Borneo, and Palawan to Indochina and the Malay Peninsula. These changes permitted the initial human migrations into the region, perhaps as long as 50,000 years ago. However, because of the persistence of water gaps of up to 50 km, these first explorers must have been in possession of simple but seaworthy craft (Shutler and Shutler 1975:10, 31, 33; White 1979:358). Though the last major glaciation was ending by about 11,000 years ago, the seas did not reach their current level until sometimes between 6000 B.C. and 2500 B.C. (Shutler 1971:14; Green 1979:34; White 1979:366; Shutler and Shutler 1975:23).

The first inhabitants of Melanesia were probably non-Austronesian peoples. Today this language group is represented by speakers of the Papuan languages of New Guinea. They were followed sometime between 4000 and 7000 years ago by speakers of Austronesian tongues, those found all across the rest of the Pacific (White 1979:354). It is possible to trace the eastward movement of these people through the archaeological record. A unique ceramic complex, called Lapita after the initial site on New Caledonia, marks their progress across 3000 km of ocean from New Britain to the Fiji-Tonga-Samoa area, cradle of the proto-Polynesians. To date, these finds have fallen in the 1600 B.C. to 500 B.C. range according to C-14 analysis. They have been associated with other evidence of human activity including pig bones, storage pits, and fish hooks. The carriers of Lapita culture reached Fiji and Tonga late in the second millennium B.C. and Samoa shortly thereafter. The distribution of the pottery design

elements themselves suggests a system of exchange among islands which may later have broken down due to the increasing self-sufficiency within the island groups (Allen 1977:389; D. Lewis 1978b:56; Kirch 1978:1, 11, 13, 1980:40). The requirements of and need for a seafaring capacity suitable to such trade are supported by two facts of geography.

It is possible to sail from Indonesia into Polynesia without ever crossing more than 500 km of open water at a stretch, though likely routes include greater gaps. Further, computer analysis of wind and current patterns has indicated that there is virtually no possibility of simply drifting from western Melanesia to Fiji (Levison et al. 1973; D. Lewis 1978b:163, 1972:25). Though we can have no absolute knowledge of the navigational techniques used by these Melanesian and Polynesian ancestors, it is likely that their apparently purposeful voyages must have been guided by something akin to the systems used by their descendants.

A long sojourn in the Fiji-Tonga-Samoa triangle preceded further migrations to the islands of eastern Polynesia. Finney (1979b:344) suggests this respite was necessary for perfection of the double canoe which would carry these voyagers over the greater distances separating the smaller islands under the rising sun. By sometime between A.D. 500 and A.D. 1000 all the various island groups of the Pacific including New Zealand, Hawaii, and Easter Island at the remote corners of the Polynesian triangle, had been settled (Bellwood 1979a:297; Kirch 1980:41). Before this great expansion, the Lapita ceramic tradition was lost, probably about the time of Christ (Shutler and Shutler 1975:81; Bellwood 1979a:311). The earliest datable

material in this part of the Pacific comes from about A.D. 300 in the Marquesas. This was a likely dispersal center for the colonization of Hawaii, Easter Island, and the Societies, though other plausible schemes can be derived from the evidence (Bellwood 1979a:323-325). Physical anthropology and linguistic analysis also support the basic unity of the Polynesian population (Howells 1979:277-283; Clark 1979:261-263; D. Lewis 1978b:60). In contrast to this generally west-to-east movement, the Polynesian outlier islands in Melanesian and Micronesian waters were populated in a secondary series of back-migrations. This probably took place over the course of perhaps 2000 years, though the earliest ceramic-bearing inhabitants may have been non-Polynesians (Shutler and Shutler 1975:87-89, 99). Since wind and current were, in this case, favorable, some of these discoveries may have been by accidental drift (D. Lewis 1978b:67).

The development of a Micronesian settlement scheme is hindered by the paucity of archaeological material. Most subsurface investigation has occurred only in the last few years and more work must be done before anything approaching a comprehensive picture can be drawn. We can, however, sketch the broad outlines of early habitation based on current knowledge. Physical anthropology and similarities in fishing gear have led some to propose this area as a major route of advancing Polynesian peoples moving east from Southeast Asia (Howells 1973). But more recent ceramic and linguistic evidence seems to contradict such claims (Bellwood 1979a:281; Craib 1983:922). It is now thought that there were at least two initial incursions, one in the west and another at the region's eastern fringes.

Researchers have long pointed to various affinities between

western Micronesia and insular Southeast Asia. In the Marianas and Palau ceramics, linguistics, and evidence of rice culture suggest early links with the Philippines (Spoehr 1957:174). Archaeologically-derived artistic motifs, house styles, and domestic animals on Palau all have Philippine or Indonesian parallels (Craib 1983:923).

Åkerblom (1968:152) cites the linguistic work of Dyen to link Palau, northern Celebes, and the Marianas. The earliest C-14 dates are from Saipan where oyster shell remains were dated to 1527 B.C. \pm 200 (Spoehr 1957:168). Though the accuracy of this date has been questioned (Bellwood 1979a:282), other evidence from Palau indicated occupation of similar antiquity (Craib 1983:923). Despite his reservations, Bellwood (1979a:282, 285, 1979b:11) concludes that Palau, the Marianas, and possibly Yap were settled from Indonesia or the Philippines in the mid-second millennium B.C., about the same time as the Lapita penetration of Melanesia.

Significantly, the Palaus lie under a flyway to Japan and the Philippines (Lewthwaite 1967:72). Bird migrations along these routes could have alerted early navigators to the existence of distant lands. The Marianas are 1500 km to windward of the Philippines and over 600 km from the nearest atoll (D. Lewis 1978a:46). Trade beads from Palau dated to 200 B.C. provide evidence of early, continued contact between Micronesia and Asia (Lewthwaite 1967:75; Shutler and Shutler 1975:93). Such contact would require some fairly sophisticated system of wayfinding to be practicable on a regular basis.

The other point of initial influx was somewhere at the eastern end of the Carolines chain or in the Marshalls. Arriving voyagers probably came from the islands of eastern Melanesia. Radiocarbon

dates of nearly 2000 years ago have been obtained from Majuro in the Marshalls, though thorough archaeological investigation has only just begun in this area. Slightly later dates come from Ponape and Kosrae (formerly Kusaie) in the Carolines (Craib 183:924). Melanesian movements into these areas are supported by similarities in fishing gear (Bellwood 1979a:282). Local traditions maintain that the atolls between Truk in the east and the Yap-Palau area in the west were settled from the east, the Trukese themselves arriving from Ponape and Kosrae. This notion is supported by linguistic analysis which divides nuclear Micronesian from the Western Austronesian spoken on Palau and the Marianas (Gladwin 1970:4; Craib 1983:922). The former tongues have a grammar related to Melanesian languages, especially those of the New Hebrides (now Vanuatu) and the Banks group (Golson 1972:15; Bellwood 1979a:130). However, the picture is not quite so simple as "east meets west at Yap." Recent archaeological finds from nuclear Micronesian-speaking Ulithi have yielded dates akin to those of the eastern islands but far older than any from neighboring atolls. This suggests the possibility that folk from the western high islands may have inhabited the atolls prior to the arrival of voyagers from the east. Alternately, it may indicate that the westward move from Truk took place far earlier than is suspected (Craib 1983:924).

Though certain elements of oceanic prehistory such as the basic unity of Polynesian culture, are beyond dispute, there remain many questions that may only be answered by more complete exposure of the archaeological record joined with ecological and biogeographic analyses. One paradox juxtaposes archaeological finds, which indicate a fairly rapid movement from Indonesia into Polynesia during the

second millennium B.C. and glottochronological studies which suggest that Polynesian languages originated in Melanesia about 3000 B.C. (Bellwood 1979a:423).

A familiar question regarding the long voyages required to populate the far-flung islands of Polynesia and Micronesia is, Why? Why should island dwellers commit themselves to the uncertainties of unknown seas? This question is of more than passing interest since without motive, one might conclude à la Sharp (1964), that the peopling of much of the Pacific resulted from a series of fortuitous accidents. The computer simulations referred to above both support and oppose this notion. They clearly show the impossibility or extremely small likelihood of accidental drift accounting for many of the population transfers known to have occurred. On the other hand, the same work points out that the time depth of human habitation in the Pacific revealed by recent archaeology combined with only moderate growth of quite small initial populations is sufficient to account for the number of inhabitants found at European contact (Levison et al. 1973:4, passim).

Oral history and reports from post-contact times tip the balance in favor of extensive intentional exploration, a necessary condition for invention of a navigational system. Of course, underlying pressures of an ecological or demographic nature may be sufficient to account for the overall movement from the Asian homeland and through the multitude of island. But long-distance voyages have also been inspired by a desire to undertake or need to escape conquest, voluntary or forced exile caused by internal dispute, trade, fishing, pride, or merely for adventure (Dodd 1972:30; D. Lewis

1972:277-291). D. Lewis (1972:289) points out that ancient navigators did not share our modern capacities for risk assessment. This made them at once more conservative (of tried and true methods) and bolder in their willingness to apply those methods without the same tools and information demanded by modern sailors. In a telling comment, Makemson (1941:3) notes that Oceanic ancestors knew only island-studded seas. Their early groupings to the east confirmed their understanding of the world surrounding them and they pushed on, expecting always to find more waystations. Fortunately for them, they were often enough correct.

We have seen how some of the first Carolinians were probably derived from the same Lapita stock as early Polynesians, moving north from Melanesia to occupy the Marshalls and eastern Carolines no later than the first centuries of our own era. It is perfectly possible that their arrival was considerably earlier. Only further archaeological work could confirm this notion. There is no way of knowing the exact state of their navigational art at arrival, but every reason to believe that they had already acquired considerable sophistication.

One should not imagine, however, that once ensconced in their "corner" of the Pacific, the Carolinians remained isolated from their Austronesian cousins. Haddon (1937:51) notes that there was a Micronesian zone of influence along the islands of northeastern Melanesia as far east as Santa Cruz. This last group was linked to Micronesia by sail affinities and outrigger attachment similar to those of Ponape or the central Carolines. Western Carolines legends include tales of attacks by Melanesians in double canoes. In the

early nineteenth century 30 Papuans raided some of these islands and there were later hostile visits by Papuans and Ternate Islanders from near Sulawesi (now Celebes) in Indonesia. Early European explorers found Malay speakers and Papuan descendants in the area. A weaving loom particular to Micronesia is found along only one stretch of the New Guinea coast. This shore was probably home to these raiders (Simmons et al. 1965:136). This same loom, absent in Polynesia, is also found in Santa Cruz and Ontong Java (Haddon 1937:51).

The Ontong Javans are linked linguistically and by material culture to both Polynesian and Micronesian areas. Physiognomical evidence indicates close Micronesian ties while blood genetics reveal great variety within the group itself (Bayliss-Smith 1978:42). It will be recalled that Ontong Java was the home of a wind compass and star lore akin to that from both Polynesia and Micronesia. Within the Carolines chain there was, as we have seen, evidence of an overlap between the linguistically distinct eastern and western populations. Further support is found in the traditions of Tobi, Merir, Sonsorol, and Pulo Anna at the extreme southwest corner of the region. The inhabitants trace their origins to Ulithi, 1000 km to the northeast, by way of Yap (Simmons et al. 1965:136). These islands are but a navigational stone's throw from Indonesia.

That the remote ancestors of Carolinian seafarers came from Indonesia can hardly be doubted. Biological evidence provides additional confirmation. Before European contact it appears that the coconut was restricted to the central and western Pacific, Malaysia, and the Indian Ocean (Sauer 1971:317). This distribution suggests a Malayo-Indonesian dispersal center. While this particular plant

cannot provide sure proof of human movement since seaborne nuts travel well and germinate easily (Sauer 1971:312-313), other Asian domesticates such as yam and taro require human intervention to cross oceans (Yen 1971:4). An Asian chicken species, Gallus gallus, is used all across the Pacific for gaming purposes. The males of Ponape and Sumatra are very similar, while the females differ, probably due to greater domestication of and attempts to breed the latter (Ball 1933:5-6, 19). Such biological domesticates provide particularly good evidence for tracing human movements since they cannot be reinvented or modified as much as inanimate objects. In addition, there is an extremely low potential for the parallel evolution of separate populations of a given species or of the convergence of differing forms (Carter 1974:202; Jett 1971:23).

Some evidence for continued contacts between these areas, i.e. raids, trade, has already been noted. The existence of agricultural terraces, rice cultures, and certain trade goods argues for post-settlement voyaging between Asia and the Palaus and Marianas. Some even cite similarities in fishing gear, sling stones, and burial customs to suggest a Marianas-Japan link (Shutler and Shutler 1975:94). One cannot, however, give much credence to hints of very late, long-range contact between Indonesia and Polynesia. Handy (1943:28) cites incised rock carvings on Hiva Oa in the Marquesas identified as fourteenth century Madjapahit (old Javanese) script. Such evidence is problematic at very best and must be viewed with circumspection.

We turn now to specifically seafaring traits that illustrate similarities and differences among Indo-Oceanic peoples. The

monumental three-volume Canoes of Oceania by Haddon and Hornell (1936-1938) underscores the basic unity of this region's nautical traditions. Doran (1981) completes and modifies the picture to reflect advances in the study of prehistory made in recent decades. This overarching unity is demonstrated in a remarkable list of canoe name cognates culled by Doran (1981:19) from all across the Indo-Pacific:

Hawaii	wa'a
Tahiti	va'a
Tonga	vaka
Fiji	wangga
New Britain/New Ireland	oanga
New Guinea's eastern tip	waga
Banda (Indonesia)	haka
Philippines	banka
Madagascar	laka

No brief survey of this knowledge could possibly be presented here in any meaningful way. We will confine ourselves to an examination of salient and significant features typical of key locales in our schema.

The assertion by Bowen (1953:82) that sail types diffuse more easily than hull types seems a reasonable one. His statement that only hull similarities prove contact could be true but, barring a series of spectacular archaeological finds, is now untestable. Unfortunately, Doran's (1981) excellent trait distribution maps did not generally include specific hull configurations. He limited himself to the broader categories of single versus double hulls, with or without outriggers. The one exception is instructive. Shunting is a technique for changing a craft's direction with respect to the wind. In the course of the maneuver, the vessel's bow becomes its stern and vice versa, the sail, or perhaps the entire rigging, being moved from

usually been called the Oceanic lateen, both areas are seen to use spritsails, albeit of different types. Doran dubs the Oceanic lateen a "crane spritsail." The spritsail was found not only in Sri Lanka, but in the Maldives, Madagascar, Yemen, Sumatra, and on an early nineteenth-century Red Sea Arab vessel as well. In addition both Sri Lankan and Micronesian voyagers occasionally used a quarter rudder for steering while directing their canoes by means of sheet alone when close hauled. We have already cited Pliny's first-century A.D. report of Sri Lankan craft sailed either end forward. Thus, shunting probably developed around Celebes (Sulawesi), perhaps as early as 1000 B.C. to 500 B.C. (Doran 1981:78, 80, 91; Bowen 1953:85). The Indian Ocean distribution of single outrigger craft expectedly follows that of shunting, covering such areas as Madagascar and the Comoros, southern India, Sri Lanka, the Maldives, Andamans, and Nicobars (Bowen 1953:87).

Another clue is provided by a sail construction technique common to the Marianas and Madura, the latter a site whose sidereal compass evidence has been described above. This type of fabrication, in which the seams run perpendicular to the yard, affords greater strength to long, narrow sails (Bowen 1953:98-99). Either Java or Sumatra was the probable home to two basic types of Oceanic lateen (Doran's crane spritsail) since both the Micronesian and Madurese varieties find prototypes in those waters (Bowen 1953:101). As a result of these and other comparisons, Doran (1981:21, Fig. 50) concludes that Sulawesi was the "center of complexity of Austronesian boat traits."

Numerous additional sail and rig affinities could be cited

from across the Pacific (Horridge 1981:29; Bowen 1953:99) as well as the Coromandel (India)-to-Brazil sailing raft tradition sharing common terminology as well as technique (Doran 1971; D. Lewis 1978b:94). These attributes from nautical tradition as well as other archaeological and ethnographic evidence have led some archaeologists to stress the similarities among Pacific cultures even over and above the broad tripartite division of the area (Frost 1979:77-78; Clark and Terrell 1978:298). Of particular interest to our investigation is the striking resemblance of certain specific traits marking a rudimentary cluster of seafaring characteristics that might demonstrate additional links among some widely separated areas of the Indian and Pacific Oceans through the intermediary of Indonesia. To further explore this potential, we turn our attention once again to the Indian Ocean.

Unfortunately, information on the seafaring traditions of the islands lying between Indonesia and the African coast is scanty. West of the Malay Peninsula and north of Sumatra are the Andaman and Nicobar Islands. Early Chinese and Arab sources stress the racial differences of the inhabitants, the Andamans being peopled by dark-skinned folk without vessels of any kind, the Nicobars by a yam-eating, Malay-like people with canoes (Ferrand 1913:37, 1922:143; Hourani 1951:71; Yusuf 1955:79-80). But there is even some confusion over which group was which (Ferrand 1914:338).

On the Coromandel (southeast) coast of India, seagoing rafts carried rigging that showed some Arab influence but was essentially of Indonesian origin. Such features as the boom, the position and form of the mast and the seam direction of the sails all came from the east (Bowen 1953:110-111).

The Maldives and Laccadives may well have been a meeting point for various seafaring traditions. Mat and batten sails reminiscent of the Chinese are reported in the Maldives (Needham 1971:599), though the extent of early Chinese penetration to the west has been much disputed (Hourani 1947:157; Tibbetts 1957:2n.3; Nelson 1961:18; Wolters 1967:146; Chittick 1970:100-101; Hudson 1970:161-163; Needham 1970:140, 1971:490, 494; Jett 1978:620). Sulayman's ninth-century account of the area noted the artistic quality of the local boats. About A.D. 1340 Ibn al-Wardi described their large boats of many small pieces of wood. Neither of these chroniclers mentions the existence of an Arab population on the islands, though an early fourteenth-century Arab geographer records their presence. Ibn Batuta mentioned trade voyages from the Maldives to Calicut on the facing Indian coast but failed to note any information on vessel construction or navigation (Ferrand 1914:389, 415, 434, 1922:32). It is appropriate to recall here that Prinsep's (1836:788) source for the Arab rose pictured in Figure 7 was a book in the possession of a Maldives captain, though its inspiration was likely Arabian Peninsular rather than local.

Though outrigger and sail were unknown on Madagascar's African-facing coast in the historic period, their presence was evident on the eastern side as well as in the Comoros and up the African littoral (Linton 1943:79). Malagasy sailors were said to have crossed the Mozambique Channel to raid the Comoros and the mainland during the eighteenth and nineteenth centuries. They traveled in light, outriggered craft steered by means of a large oar and using only the stars to guide them (Ferrand 1919:153; Hornell 1934:318).

Arab presence was established in Madagascar sometime between the seventh and twelfth centuries (Ferrand 1908:499; Linton 1943:76; Nadvi 1942), probably about A.D. 1000. The late thirteenth-century Arab geographer al-Mujawir spoke of al-Komr, the people of Madagascar, combining three monsoon sailing seasons into one by making a direct run from their homeland to Aden, an area previously conquered and later lost by their ancestors. His contemporary, Ibn Sa'id had al-Komr arriving in Aden the first time in successive waves from Upper Asia, India, and Indonesia (Ferrand 1919:147-151). Ferrand uses inconsistencies in the report to cast doubt on the compressed northward journey but postulates an initial movement of al-Komr from western Indonesia along the coasts to Arabia. Also of note is the uninhabited state of the Chagos, Seychelles, Réunion, and Mauritius at European arrival, despite their suitability for colonization (Linton 1943:78). There is also evidence of Indonesian presence in Azania, the African coasts from Somalia to Tanzania, before A.D. 1200 (Murdock 1959:214). It is entirely possible that a small migration missed the mid-ocean islands or that evidence of earlier occupation awaits further archaeological investigation.

We know, as has been noted, that at some point in the past, perhaps about 2000 years ago, Madagascar was peopled by seafaring groups whose homeland was among the islands of Indonesia. It remains only to mention a few additional Austronesian traits which reveal this movement. On the East African coast were found four separate instances of a particular type of outrigger boom-to-stanchion attachment. The only other occurrence of this feature in the entire Indo-Pacific region is in northern Java (Hornell 1919:98). Other

Indonesian locales have been cited as the possible origin of these migrations. Dyen sees a relationship between Malagasy and the Maanyan language of Borneo, calculating a 1900-year separation between the two. Botanical evidence includes a host of Asian domesticates common to both areas. Among them are rice, taro, yam, banana, breadfruit and coconut. Other shared traits include a flat-bar zither found only in East Africa, Madagascar, and Indonesia, the use of lampreys to capture sea turtles and the mtepe, a sennit-lashed plank boat. Malagasy social organization and kinship terminology is also reminiscent of Indonesia (Murdock 1959:208-209, 220).

This great westward movement of an Austronesian people, already accomplished mariners, could well have been a mechanism by which navigational knowledge traversed the Indian Ocean. Across the sea, the Socotra-Laccadives route was "routinely" plied by Arab voyagers 2000 years ago (Grosset-Grange 1972c:8) and Indian names for sandalwood and some spices appear in pre-Islamic Arab poetry (Siddiqi 1957:275).

Traditional Arab seafaring was not limited to the Arabian Sea, however. Broader contacts over the entire breadth of the Indian Ocean could have put these seamen in touch with navigational systems of other maritime cultures and allowed them, in turn, to develop their own methods. Though there was undoubtedly trade between China and the Arabian Peninsula-Persian Gulf region from very early on, it is not clear exactly when Arab bottoms entered this commerce. Arabs were certainly present in China from the eighth century since they are mentioned in accounts of the A.D. 758 sacking of Canton. But it may not have been before the following century that their own ships

reached Chinese ports (Ferrand 1913:3; Lewicki 1935:173-176). They had probably reached Indochina between the sixth and seventh centuries (Di Meglio 1970:127). The Arabs went on to displace the Persians in the Southeast Asia trade, controlling it from the ninth through the fifteenth centuries. Nonetheless, Islam seems not to have reached the Philippines, for example, until the twelfth century; the earliest Arab grave there is dated to A.D. 1310 (Majul 1966:63-67).

Though the record is confused, Arab presence in Indonesia seems considerably older. If Arabs had, indeed, reached Indochina by the sixth or seventh century, it is probable that the adjacent island world became known to them during the same period. Corroborating, though not definitive evidence comes in the form of East African slaves called zang or zeng by the Arabs, reported in Indonesia at about this time. Chinese records show black slaves, seng-k'i, offered in tribute in 724 and again in 813 by subject kingdoms in Sumatra and Java (Ferrand 1919:96-97; Hornell 1934:306-307). These slaves could conceivably have been carried in Persian and/or Chinese ships. But there is no record of such trade by those groups and it is much more logical to attribute such cargo to Arab merchants.

Evidence for Arab presence in the region in the form of an A.D. 848 Abbasid coin from Kedah, Malaya, and a Muslim grave in eastern Java dated 1082 or 1101 is, by itself, tenuous (Tibbetts 1957:33, 35; Coedès 1968:241; Ricklefs 1981:3). The coin could have been carried by others and at a much later date. The gravestone, too, could have come from afar. In any event, there were also Persian, Indian, and Chinese Muslims in the vicinity. Nonetheless, Tibbetts (1957:17) concludes that by the late ninth century Arab traders were

well acquainted with the geography of Malaya and Sumatra and handled a long list of products. One thing is certain: by the time of Marco Polo's 1292 visit to Perlak, a Muslim town in Sumatra, the influence of Islam was widespread in the region. This was due, in no small measure, to the efforts of seaborne Arabs whose activities in the area were likely several centuries old (Ricklefs 1981:3; Coedès 1968:202).

In this chapter we have sought to explore the archaeological and historical records for evidence that might corroborate either the case for independent invention of sidereal compass systems in the Indian and Pacific Oceans or the case for some sort of diffusion of the idea from one realm to the other or to both from a common source. As with the astronomical calculations, the data presented are in several instances suggestive but not conclusive if considered alone. It is certain that Austronesian and Arab groups, seafarers among them, came into contact with one another on both sides of the Indian Ocean and, perhaps, several intermediate locations. The possibility of the exchange of navigational information during such contacts remains, but the lack of sure references clouds the picture. By the time the Arabs entered the Indonesian world, its inhabitants had already been long under the influence of Hindu culture (and astronomy?) and Sanskrit language (Ferrand 1919:195, 226; Bowen 1953:84-85; Mookerji 1962:103). In African waters, be it Aden, Azania, or Madagascar, there can be little doubt of contacts. But their nature remains equally obscure. Our final task, then, is to integrate and analyze the bits and pieces along with the few solid points of reference, all in light of the theoretical framework established in Chapter III.

CHAPTER VI

SUMMARY ANALYSIS AND CONCLUSIONS

We will now summarize the principal elements of the foregoing discussion and analyze them according to criteria established in Chapter III. This will be done in the form of two hypothetical schema, one based on the diffusion of the sidereal compass between two or among several groups, the other on its independent invention in two or more locales. These will be developed simultaneously as the criteria are discussed with respect to both an "ideal" case and our current knowledge. Should our data fall short of fulfilling those conditions, we will speculate on what sort of additional evidence, if any, might confirm either hypothesis. Finally, overall conclusions will be drawn.

Seven criteria were laid down for the testing of hypotheses regarding the independent invention versus the diffusion of a cultural trait, be that trait concrete or abstract. The categories were: specificity, arbitrariness, degree of resemblance, relative time depth, existence of a developmental sequence, trait clustering, and the possibility of and evidence for contact.

Were our subject an ideal case of independent invention (recall that we have assumed the independence of the compasses as a working hypothesis), the sidereal compass might be a trait of such universal distribution that it could only be the product of some pan-human need (e.g. kinship organization or funerary customs, to pick extreme examples). In the case of a more restricted distribution, one

would want to demonstrate sufficiently strong similarities in the environments of its possessors that parallels in the compasses could be ascribed to ecological imperatives. Resemblance between the compasses themselves should be relatively weak. The appearance of the compass in the two societies would be of such a temporal disparity that the supposed donor culture could not have passed the trait to the recipients, mandating a conclusion of separate inspiration.

Similarly, distinct developmental sequences from rudimentary to more refined (and perhaps back to degenerate) forms of the compass in each culture without evidence of successive transmission of the different stages from one to the other would provide a strong argument for independent invention. The trait's isolation, the lack of a cluster of related traits which might have diffused alongside it, would weaken any attempts to prove common heritage. Finally, evidence for contact between the various compass cultures should be weak or non-existent.

There is no doubt as to the specificity of the sidereal compass. Though it certainly serves a universal human need for wayfinding, it cannot, in itself, be seen as the necessary product of attempts to elaborate navigational systems. Its sporadic distribution alone would belie such a claim. On the other hand, the degree to which it might be labeled arbitrary is much more complicated. The fact that all known examples of the compass are from seafaring cultures argues strongly for its environmental dependence. The night sky is visible to all and sailors the world over face similar problems of wayfinding. It is perhaps not so remarkable that Polynesians, Persians, Phoenicians, and Chinese alike (D. Lewis 1978b:76) have bent the regularity of celestial phenomena to their own ends by developing

systems that allowed them to traverse the broad seas.

The visible workings of the sky can be put in even wider perspective. One reevaluation of myth and legend from around the world does not explain the cataclysmic events contained therein as interpretations of actual occurrences on earth. Instead, they are linked to the advent of "new ages" when precessional changes disrupt the old conjunctions of solar and stellar calendars and the regulation of human affairs that had been guided by them (de Santillana and von Dechend 1969; Reiche 1979). This interpretation need not alter our search for compass origins. Several points are worth mentioning, however. The use of Canopus to represent the south pole is found in many archaic traditions. Its Arabic name, Subail, comes from sahel, presumably meaning "south." This designation could be linked to its proximity to the large Magellanic Cloud near the south pole (de Santillana and von Dechend 1969:269n.16). This, combined with its standing as the second brightest star (after Sirius) in our heavens, might well account for its prominence.

We now turn to another source of considerable uncertainty in our investigation. It has been noted that the solstitial colure, the great circle passing through the celestial poles and intersecting the ecliptic at the solstitial points, passed through Aquila just over 2000 years ago (de Santillana and von Dechend 1969:236n.13). Our calculations show that Altair, in Aquila, rose at about dawn on the winter solstice in this time. Combined with its low Declination, this significant rising time could have led to its assumption of a prominent role in Arab astronomy. Finally, the emphasis of these works on the universal nature of heavenly phenomena and the strikingly

common theme of many myths from widely separated cultures, serves to remind that the raw material of celestial constructs was almost ubiquitous. It cautions against too-ready acceptance of a few similarities as proof of diffusion. Surely, much that is common to seafaring traditions from remote quarters of the globe is the result of the application of human genius to the universal demands of nautical endeavor.

Nonetheless, the inventionists cannot rest their case on this point. The peculiarly tropical nature of star compass navigation restricts its likely place of origin. Such a system was probably born close to the equator. Could Arab seafarers have ventured so far south without it only to develop it on their own? Coastwise voyaging around the Arabian Sea to the south of India or even latitude sailing driven by monsoon winds and navigated by the height of circumpolar stars could clearly have permitted this. But these same preliminary steps could also have placed them in contact with Austronesian navigators with a compass system already elaborated. On the other hand, the southern Arabian Peninsula and Socotra are well within the tropics.

The three principal subjects of our investigation, the Carolinian, Arab, and Madurese compasses, display strong resemblances as well as some differences. The salient features are the sharing of 18 of 32 azimuths by the first two and the use of Altair to designate east in all three. Since one cannot attribute Altair's use to an actual, observable phenomenon or to some non-navigational importance in each culture, this must carry great weight. Alternately, the paucity of sure data from Madura, Tonga, Hawaii, and other venues of suggested compass use undermines the strength of any

attempt to show pan-Pacific resemblances. Furthermore, the Arab association of sidereal and magnetic rhumbs hinders close stylistic comparison to the Carolinian compass, notwithstanding our argument that this was a fairly recent alternation of an earlier Arab compass.

Muller (1971:67-77) has warned against the excessive use of superficial style or form in diffusion arguments. A more powerful explanation must also demonstrate structural parallels which reflect organizational principles. As an abstract representation of a part of the real world and a systematization of useful knowledge permitting the successful completion of concrete tasks, the compass provides such parallels. Beyond the common use of specific star points, it does reflect a cross-cultural organizational unity.

The question of relative time depth is particularly thorny. The Austronesian cultures were non-literate until their contact with outsiders - Hindus, Chinese, Arabs, Europeans. Though Arab chronicles exist, there was no travel or geographic literature before the ninth century with the exception of translations of Ptolemy (Tibbetts 1957:31). Shortly before this date Arab ships had first reached Indonesia. By this time, however, most or all of Oceania had been settled and Austronesian pioneers had been in Madagascar for centuries. Seafaring between these various zones was in Arab, Chinese, and Persian hands, later to be swept aside by the European tide from both east and west. The historical record shows no sign of Austronesian voyaging. In light of this scanty record, the relative merits of diffusionist and inventionist arguments cannot be sorted out.

In an attempt to fill this evidenciary chasm, we have argued,

neither the diffusionist nor the independent inventionist cause can claim clear support in this matter. An Arab compass representation from before the time of magnetic rose influence would contribute to the clarification of this point.

The existence of a developmental sequence in any compass venue would have been a boon to unraveling the mysteries of the origins of all such examples. Unfortunately, no such sequence exists. Distinct sequences would tend to support the notion of separate invention and development. But their absence cannot be seen as a buttress for the diffusionist interpretation. In this case we simply have no evidence. The abstract nature of our trait and non-literate character of many of the cultures in question could hide changes that may well have taken place. This raises the possibility that different stars were used for various bearings in the past (Tibbetts 1971:295). Such a discovery could facilitate the interpretation of what now appear as inconsistencies. It might also aid in the temporal pinpointing of compass origins. However, if the stars did change, the coincidence of azimuths in Arab and Carolinian representations would be all the more remarkable and more difficult to attribute to separate development.

The diffusionist case would be strengthened by the finding that the compass was only one element of a trait cluster that appeared in the various possessor cultures. Indeed, this has been shown to be the case with respect to horizon star use throughout Polynesia. All across Oceania, in fact, a complex of seafaring tools including vessel types and handling techniques, and navigational practices, including the compass, display a high degree of uniformity from one area to another. Some of the constituents can be identified in Indonesia and

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others as far afield as Madagascar. We have seen evidence for Arab use of the Southern Cross, though it does not appear in their compass. This by itself means little. The only Oceanic traits which appear in the Arab seafaring repertoire are Majid's description of fore-and-aft sailing, whereby a craft is aligned between stars on opposite horizons, and hints of a concept similar to the notion of a central portion of the sky containing "roads" followed by groups of stars. The potential use of linguistic similarities is completely absent. In fact, the Persian root of some Arab star names forces one to look north rather than east. Horridge (1981:84) notes that a complicated cultural artifact borrowed from abroad is often accompanied by its original name. Even in the case of an Arab-Persian link, we have only a few words to support such a notion. This relative isolation of the Arab construct offers strong testimony for its independent or, at least, northern origin. Conversely, there are no Arabic star names associated with the Pacific compasses. On the other hand, both areas probably had their own star names long before the invention of the sidereal compass. There is no reason to assume that particular star names must have diffused with the idea of forming those stars into a compass system.

It might be argued that the compass itself constitutes a trait cluster. It is a combination of star paths into both an abstract system of directional orientation and a practical tool for guidance at sea. Its use requires the combination of other navigational techniques to balance the effects of wind and current and enhance the chances of accurate landfall. Unfortunately, little is known of early Arab navigational practice and later usage relied heavily on latitude

sailing. Thus, an acceptable trait cluster common to both Indian Ocean and Pacific worlds cannot be demonstrated. Furthermore, even if we accept the compasses as parallel clusters, an inventionist argument for complex demand could account for the similarities. Some element of the cluster, the directional use of horizon stars for example, might constitute the nucleus of the cluster, arrived at independently in both places. The logic of navigational elaboration would then be said to guide the expansion of that nucleus into a complete compass.

The multifarious nature of the similarities of Polynesian cultures and the evidence of contact both in oral tradition and the archaeological record among the scattered island groups, leave no doubt about the common origin of many of the region's navigational practices. However, the links between Polynesia, Micronesia, and Indonesia, and the Arab world are not as clear. Certainly, as has been shown above, the possibility of contact existed. Each of these areas was possessed of a nautical tradition sufficiently sure as to enable its practitioners to contact the others. What is lacking is the hard evidence that these contacts actually occurred.

We have seen that the Arab incursion into Indonesia took place millennia after the first waves of Austronesians moved through the area and centuries after the probable date of the colonization of Madagascar. But we have also outlined evidence of continued Micronesian-Indonesian contact in the form of raiding or trading voyages which probably extended into the era of European contact. It seems more likely, though, that Arab and Austronesian met during the latter's expansion into the Indian Ocean. If the eventual settlers of Madagascar made their way by a northern route, they might have crossed

paths with their Semitic counterparts in Sri Lanka, southern India, the Maldives or Laccadives, or along Arabian or Azanian shores. The route is a likely one for voyagers seeking new lands. They might actually have gleaned some notion of the direction from early Sanskrit-speaking arrivals to Indonesia. It would have been a more logical course than to sail southwest into unknown waters. And we know that Arab voyagers were already traversing the Arabian Sea at the appropriate time. The conjunction between the dates of these early ventures and that of our calculated star positions is also suggestive. Once again, however, we are faced with ambiguity. The diffusionist case is strengthened by the real possibility, as well as some reports, of contact. The independent inventionist argument finds support in the lack of proof that a compass was ever transmitted from one group to the other.

Without evidence of much earlier and deeper Arab penetration of Oceania, it is not safe to conclude, as did Gatty (1958:36-37), that certain Pacific navigational techniques owe their inspiration to an Arab source. Such evidence could be forthcoming as archaeological investigation in the region increases. Nor are island-hopping Lapita peoples during their Melanesian sojourn likely candidates. As with Indonesians of the inner, almost landlocked seas, the nature of their voyaging would not demand such sophistication. In addition, one would not expect Melanesians, living south of the equator as they do, to choose Altair, a northern hemisphere star, to denote east. Yet we find the probable remnants of a sidereal compass (including Altair) on Madura, an "inland sea" locale at about 7°S Lat! Nonetheless, the bulk of the evidence still points to an original location that is just

north of the equator, open to long-distance sea lanes, and the center of regular voyaging in a variety of directions. Thus, it seems unlikely that Austronesians migrating west from Java or Sumatra would have originated the particular system that became the Carolinian compass. Evidence of repeated voyages and of contact with the Carolines is absent, though any such system might have reached Madura.

We must here reiterate certain points made in the theoretical discussion of Chapter III. While we have tried to examine a broad range of evidence in an organized manner, several handicaps have been forced upon us. Due to the absence of generally recognized standards for the separation of diffusion from independent invention, we have had to create our own set of criteria. This process, while resulting in a serviceable scheme, has emphasized the limitations of historical and archaeological inquiry. In cases such as ours, offering only minimal evidence, the inherent ambiguity of human affairs dominates the picture. Though it is important to apply principles of scientific inquiry, one must remember that events whose motor is human activity rarely obey the same deterministic laws as the physical universe.

Even the material world admits only degrees of probability. Absolute certainty exists only in the closed logical systems of the human mind. These systems are tremendously useful for generating principles of observation, organization, and interpretation of raw data but cannot themselves be substituted for "reality." It is in this light that we seek, next, to describe a likely scenario for the origins of Indo-Pacific sidereal compasses.

Accepting the astronomically determined dates of compass origins and integrating all the evidence presented, we can advance

certain conclusions. By at least 2000 years ago and perhaps much earlier, Austronesian seafarers left Melanesian waters to colonize the Marshalls and eastern Carolines. They carried with them a sidereally based system of sailing directions (Goodenough 1953:41) and perhaps the rudimentary organization of such directions into compass form. The same was true of their cousins who moved east into the Fiji-Tonga-Samoa triangle, eventually to spread across Polynesia.

Much earlier, up to a millennium earlier, in fact, other Austronesians, similarly equipped, pushed beyond their Philippine and eastern Indonesian homes into the Marianas and western Carolines. In this region at last, regular intercourse continued between "colonies" and homeland. Some time later, eastern Carolinians pushed west, meeting their western counterparts somewhere in the vicinity of Yap. The navigational demands of this voyaging fostered the full development of the Carolinian compass resulting in the form we see today. These trips also served to transmit this knowledge back into Indonesia, whose navigational development had also followed the sidereal path but needed the added impetus of regular, open-water crossings for the elaboration of a compass system.

Across the Indian Ocean, Arab seafarers likewise explored to the east using a sidereally based system of wayfinding of more northerly inspiration, including, perhaps, some Persian influence. Here, too, compass-like organization had probably begun. But a parallel system based on the height of the pole star was also being developed. This latitude sailing, especially useful on north-south trips in the Red Sea and Persian Gulf, was later adapted to Arabian Sea crossing as far as the coast of India (de Saussure 1928:100).

As Austronesian seafarers moved west out of the Indonesian archipelago during the last centuries B.C. or the first centuries of our own era, they were already in possession of a fairly sophisticated sidereal compass. They may even have refined and adapted it to Indian Ocean use on exploratory forays to the west. The Arab and Austronesian systems met in the islands around India's southern tip or on the shores of Arabia or Africa. There, Arab practice was modified to take advantage of the greater tropical experience embodied in the Austronesian compass. The navigation of the latter group may also have been altered under Arab influence, though no remnants survive among their descendants in Madagascar.

How the Arab compass became frozen in a 2000-year-old configuration remains a mystery. Perhaps their needs were adequately served by latitude sailing, a system well-suited to voyages terminating on long, north-south coasts rather than tiny, mid-ocean pinpoints. It is also easier to master than star compass navigational techniques. As the two systems blended, latitude sailing came to dominate but not eliminate the compass. Perhaps an early introduction of a Chinese magnetic device caused the compass star rhumbs to become mere conventions soon after their adoption (Jett 1971:13, 1978:620; Needham 1971:490, 563, though the earliest references are questioned). This scenario leaves these and many other questions unanswered. Nevertheless, we have offered a reasoned, hypothetical account which best integrates all the information currently available. It is hoped that future investigations will uncover new material that will clarify the ambiguities and correct the undoubted errors contained herein. It is likely, however, that the veil of secrecy will partially shroud

this historical puzzle forever.

Though beyond the stated goals of this effort, it is important to mention, albeit briefly, some of the implications for cultural change in general embodied in our results. Aside from the light such implications might shed on the particular events studied here, one of the prime goals of any such research should be the elucidation of more basic cultural phenomena in an attempt to understand the workings of human societies. No claim is made that the development or adoption of a particular navigational technique, even one rooted in a cognitive system with wider importance, results in major social upheaval. Gladwin (1970) stresses the central role played by navigators on Puluwat. Their essential contribution to the well-being of all makes them the most important men on the atoll. The social and economic interchange afforded by their skill and knowledge has significant survival value for their fellows, helping their societies to weather crises and to develop under often difficult conditions (Gladwin 1970:23, 35).

It has been argued, as was noted above, that cross-fertilization such as that afforded by inter-island voyaging is a necessary ingredient of cultural evolution. Unfortunately, the archaeological record often fails to reveal the non-material side of cultural exchange (Ekholm 1964:489, 1971:56-57). In order to properly understand any society in both structural and functional terms, the full range of its history need be known. Without this history, a relatively isolated culture can seem static until the advent of some outside group who interpret it to the rest of the world (Evans-Pritchard 1961:6, 11). Thus, we are greatly hampered in our

understanding of the relationships between sidereal compasses because we are ignorant of the development of any one compass within a single society. It is only by teasing out such individual threads that we can comprehend the entire fabric of the region's history. And it is only through such historical exposition that the dialectic of cultural reproduction and cultural transformation may be understood (Sahlins 1981:8, 50-51), converted, as it were, from a mystery into a tool for greater knowledge.

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APPENDIX

ASTRONOMICAL CALCULATIONS

A number of different formulas from a variety of sources were used for the computation of ancient star positions and azimuths. Declinations were worked for all the stars of the Arab, Carolinian and Madurese compasses at 500-year intervals back to 3500 B.C. Right Ascensions and azimuths were figured for a far more limited group of stars at particular intervals in order to test specific hypotheses. For the purposes of these calculations, the Carolines were assumed to lie at 8°N Lat. Arab azimuths were usually worked from 20°N Lat. Initial Declinations and Right Ascensions were taken from the 1980 American Ephemeris and Nautical Almanac. Declinations were rounded to the nearest 0.1° and Right Ascensions, converted to angular measure, to the nearest 0.5°.

The equations alone will be presented. Explanations of the astronomical and trigonometric background are available in the source material. Solutions could be worked by hand with a set of trigonometric tables or by means of computer programs. In this case a compact, programmable scientific calculator, the Sharp EL-5100S, proved a convenient compromise.

Azimuths were found by the following simple formula:

$$\cos R_z = \sin d \div \cos L$$

where R_z is the azimuth at rising, d the Declination of the star, and

L the observer's Latitude (D. Lewis 1972:311-315).

Right Ascensions for a given time, T , in the past can be found by using the equation:

$$\sin(a - z) \cos d = \sin(a_0 + x_0) \cos d_0$$

where a = R.A. at T

$$z = x_0 = 0^\circ.0002197 T^2$$

$$x_0 = 0^\circ.6402633 T + 0^\circ.0000839 T^2 + 0^\circ.000050 T^3$$

T = the number of centuries in the past expressed as a negative

d = Dec. of the star at time T

a_0 = current R.A. of the star

d_0 = current Dec. of the star

These and other formulas are available in the 1983 Astronomical Almanac (U.S. Government Printing Office 1982:B16, B18).

Declinations can also be found from equations in the Almanac. Here, however, a different, two-part procedure supplied by Dr. Roger Smith, Texas A & M University (1983:personal communication) was used. The first part is the calculation of the coordinates of the pole at a given number of years, t , before the present. This involves four steps:

1. $A = 360 (t \div 26,000) + 90^\circ$

2. $B = \arccos(\sin^2 23.5^\circ \sin A) + \cos^2 23.5^\circ$

$$3. \quad \underline{C} = \arccos(\cos A \sin 23.5^\circ \div \sin B)$$

$$4. \quad \underline{C} = \arcsin [(\cos 23.5^\circ \sin 23.5^\circ \sin A - \sin 23.5^\circ \cos 23.5^\circ) \div \sin B]$$

where A = R.A. of the ecliptic pole at time t

B = 90° - Dec. of the pole

C = R.A. of the pole at t (Both the sine and cosine of C are calculated so that its quadrant and, thereby, its value may be determined by comparing the signs.)

t = the number of years before the present

23.5° = the angle between the celestial and ecliptic poles.

26,000 = the period of the precessional cycle

The second part is the actual calculation of the star's

Declination with the pole at a given location:

$$\cos(90^\circ - d) = \cos B \sin d_0 + \sin B \sin d_0 \cos(C - a)$$

where B and C are as above

d = Dec. of the star at time t

d_0 = the current Dec. of the star

a = the current R.A. of the star

The determination of rising times is also a multi-step process. The necessary formulas and background are available in Smart (1965:41-48).

$$1. \cos H = \tan L \tan d$$

$$2. S_s = a + H$$

$$3. S_m = 6h37m + 3.94m(D)$$

$$4. I = S_s - S_m$$

$$5. T = 1.002738 I$$

where H = the hour angle of the star at setting (rising hour angle
is the negative of this value

L = Lat. of the star

d = Dec. of the star

S_s = the local sidereal time at setting

a = R.A. of the star

S_m = the local sidereal time at midnight

D = the day of the year, given January 1 as day 0

I = the interval between midnight and setting (add 24 hours
for negative values

T = Local solar time

None of the above calculations is absolutely precise. They are, however, more than close enough for purposes of naked-eye astronomical observations.

VITA

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PROFESSIONAL EXPERIENCE

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Archaeology Summer Field School excavation of sunken
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Participation included excavation, artifact conser-
vation, record keeping, and equipment maintenance.
1984 Kaş, Turkey. Institute of Nautical Archaeology
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The typist for this thesis was June Mc Shean, DATARITE Business
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