ASTRONOMY AND NAVIGATION IN POLYNESIA AND MICRONESIA

by
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The Caroline Islands

1. *General*

The Carolinian island chain extends for about 1500 miles east and west. By comparison the north-south spread is small, being at its greatest only about 250 miles. The mean latitude is about 8° N. Apart from Yap and Palau in the west, Ponape in the east and the Polynesian outliers, the inhabitants of the Caroline Islands speak closely related dialects belonging to the same language group, referred to as the Central Carolinian language area. (Goodenough, 1953, p. 2.) Within this area there exists a uniform astronomical and nautical system, which in its final form has spread to other islands within the archipelago. In one respect Yap is an exception, however. Müller has this to say about nautical knowledge on Yap: "Nach Yap scheint nur die Kunde von dem fertig ausgebildeten System gedrungen zu sein" (1917, p. 287). On the other hand Yap has not adopted the Central Carolinian calendar (time reckoning), but has retained its own quite different original one resembling most nearly the one used by the Chamorros in the Marianas (*ibid.*, p. 281).

Even if it is possible to distinguish within the Carolinian island chain certain islands and groups of islands whose culture is substantially different from that of the central Carolines, for the purposes of this survey the Carolines can be regarded as one unit because the natutical-astronomical knowledge throughout is so similar.

Goodenough has pointed out that no cosmogony or astronomical theory has been developed within the Carolines to explain the structure of the universe and the heavenly bodies and their motions, and he also notes that there is no mythology of the stars. In view of the interest the inhabitants display in divination and luck he also finds it remarkable that this has not given rise to an astrological system along the lines of that found within Polynesia. He is if opinion that this may possibly be explained by the importance of astronomy for a seafaring people: "Linked as it is with direction-finding in navigation, native astronomy is perhaps too important for personal safety to permit its being removed from an empirical context" (1953, p. 4).

It is, however, doubtful whether this view can be accepted in full. There are traces of both cosmology and star mythology within the Carolines, even if they are fragmentary and do not appear in the same

profusion as within Polynesia. The interest in ethnographical research in Micronesia got off to a late start, and it is conceivable that traditions and mythology had by that time largely been forgotten. This process would certainly have been hastened by a falling off in voyaging, resulting partly from restrictions on and prohibitions of long sea voyages imposed by the administrators. It is, moreover, uncertain to what extent the ethnographical field researchers took an interest in and reported on these aspects of the culture.

The idea that the absence of an astrological system can be explained by the fact that astronomy was altogether too important for personal safety on sea voyages to permit "its being removed from an empirical context" can hardly be accepted. This situation obtained to at least the same extent within Polynesia, where, nevertheless, a highly developed "astrological system" existed in part.

2. *Sidereal compass*

As the Carolines lie near the equator the paths of the stars are all but at right angles to the horizon. It is thus fairly easy to reconstruct their paths and determine the points on the horizon at which they rise and set. This has enabled the islanders to evolve a fixed orientation system, which makes it possible to determine direction satisfactorily during the hours of darkness. The system corresponds in some ways to a compass, and is therefore usually called the star compass or the sidereal compass.

The east-west axis of this consists of a line which joins the points at which Altair rises above and sets below the horizon. Altair has a declination of 9° N and thus passes through the zenith or in the immediate vicinity of the zenith in all parts of the Carolinian archipelago. The star is the basis of the system of navigation and when it is on the horizon it gives the navigator the direction of east and west. The path of the star corresponds approximately to what is known as the celestial equator in the celestial equator system of coordinates. In this respect, however, the compass is not exact, because true east-west and the celestial equator can be indicated only by a star whose declination is 0° (it passes through the zenith of an observer on the equator). This does not matter to the Carolinian navigator-astronomer because he does not use his compass in the way we use the magnetic compass; he does not give a certain compass bearing but instead gives his course with reference to the point on the horizon at which a star rises or sets.

The north-south axis consists of a line which joins Polaris, just visible above the horizon at these latitudes, with the Southern Cross when it

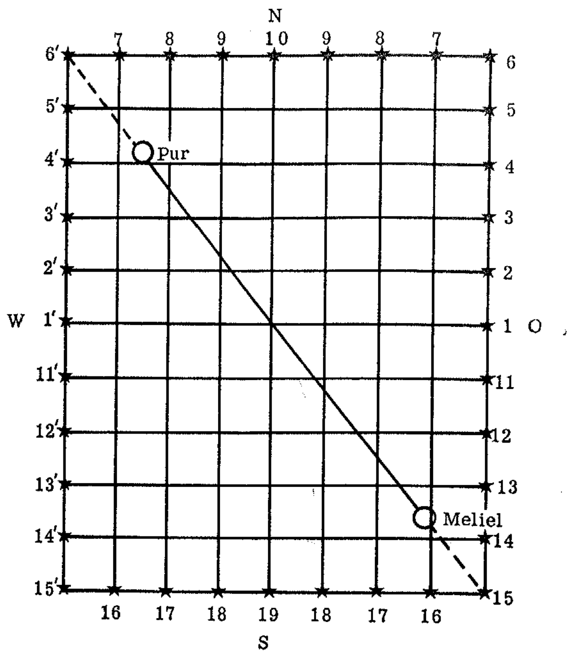


Fig. 7. Sidereal compass, Songosor (after Hambruch, 1912).

is upright (when crossing the meridian). With this the compass indicates true north-south. The great circle between these two stars (constellations) constitutes what we call the celestial meridian, and divides the celestial sphere into an eastern and a western half. The star paths have been given different names in these, depending on whether the star is rising or setting.

With this the framework of the sidereal compass has taken shape. It consists of two axes at right angles to one another, the four cardinal points and the celestial meridian. In addition to the four cardinal points the star compass is furnished with a varying number of other points, indicated by the positions on the horizon at which the stars rise and set. In the Carolines the total number of compass points, which have been named after the stars concerned, varies between 28 and 36. The declinations of the stars (or the bearing to the stars when rising and setting) have been chosen so that the compass points are fairly evenly distributed all round the horizon.

A star compass from Songosor (Sonsorol) is shown in Fig. 7 to illustrate the system. Here account is taken of nineteen stars (constellations) whose rising points (1—9; 11—18) and corresponding setting points are

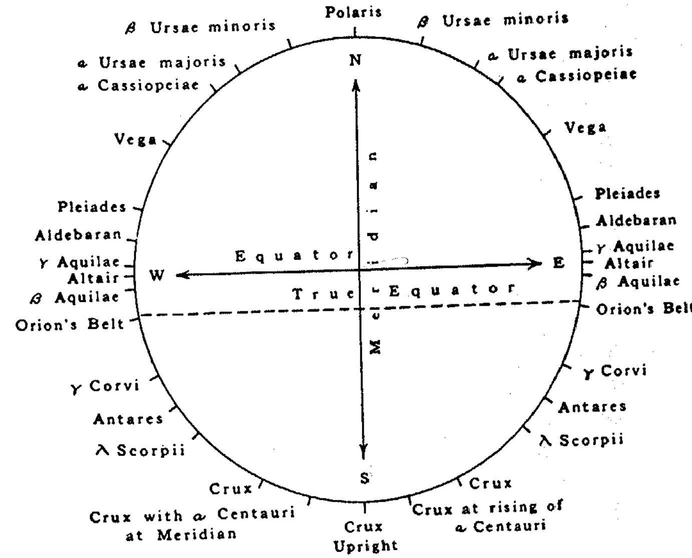


Fig. 8. Sidereal compass, Central Carolines (after Goodenough, 1951).

indicated on the horizon. Number 10 indicates Polaris and number 19 the vertical Southern Cross. The line joining 10 and 19 is the celestial meridian. Number 1 is the point on the horizon at which Altair rises, while 1′ is where it sets. The lines joining 1—1′, 2—2′, etc., represent the paths of the stars.

In general the same stars and constellations are used on all the islands. There are, however, minor differences due to geographical position and the resulting different needs for precision in indicating direction within a certain sector. The east-west orientation of the Carolines means that the longer sea voyages mostly went in these directions. This is also reflected in the sidereal compass in that the compass points are grouped somewhat more closely round the east-west axis, that is to say, a relatively larger number of stars with small declinations is used.

Goodenough has prepared the compass shown above for the central Carolines (Fig. 8), from which it is clear which stars have been selected and what are their rising and setting points on the horizon (1953, p. 6).

The compass stars are not visible, nor do they rise and set at the same time; if they did it would greatly reduce the usefulness of the compass. Instead, the stars have been selected so that during the sailing season several stars can constantly be observed at different heights above the horizon, and their rising and setting points thereby be determined. When selecting stars account has primarily been taken of the suitability for

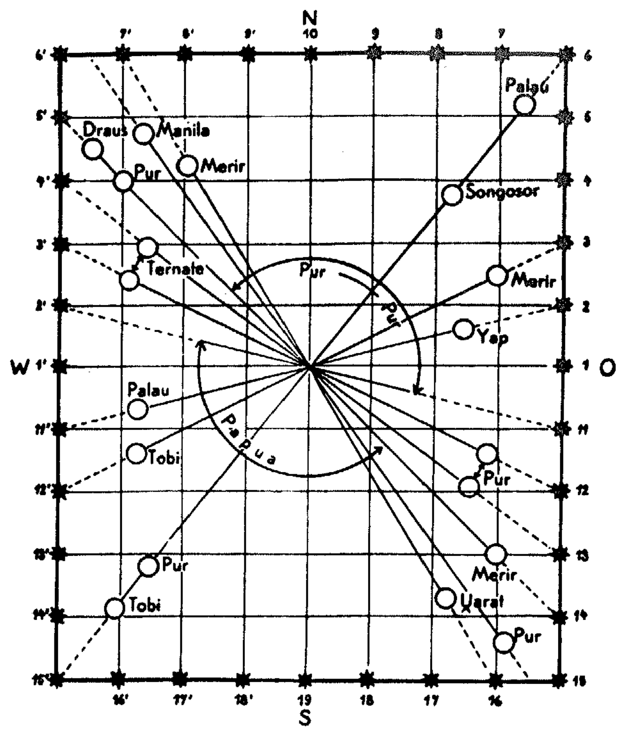


Fig. 9. Sideral compass, Pur (Pulau-Anna) (after Eilers, 1935).

navigational purposes of their declination and right ascension (rising and setting at different times), so that a favourable spread over the night sky is obtained. The magnitude of the stars has been of minor importance, which means that such bright stars as, for example, Sirius and Rigel are not included in the compass and have not even been named. (Goodenough, 1953, p. 3; Erdland, 1914, p. 78.) On the basis of one or more compass points obtained in this way the navigator can reconstruct the whole of his sidereal compass. Its usefulness is not therefore dependent on the observation and position of all the stars included in the compass. For example, the compass point "Altair" is fixed irrespective of whether that star is visible or not.

If the sidereal compass is to be of practical value, the islands known by the navigator must be placed in relation to it, that is to say, the course to the destination has to be given in relation to one of the compass points.

For a voyage between Pur (Bur) and Merir (Meliel) course is set from the point on the horizon where the star 5′ sets to the point where the star 14 rises (Fig. 9). The chart does not give the true geographical position of the islands, because the course directions have taken account of leeway and set and drift with the current. The navigator imagines himself as always being in the centre of the chart. No "charts" in the real meaning of the word exist, however. The one reproduced here is merely an ethnographical reconstruction designed to explain the principle of navigation. The Carolinian navigator was obliged to memorize the compass, the positions of the islands in relation to it, and also the necessary course directions. That these latter could amount to a considerable number is shown by the fact that on Puluwat Sarfert was informed of no fewer than 100 of them (1911, p. 134). The directions included the estimated number of days for the voyage and also gave the course direct to the destination as well as via a third island, which could serve as an alternative landing place in the event of bad weather. Together with the other two, this third island formed a triangle and served, according to Sarfert, as a "Notinsel" (1911, pp. 135—136).

As is shown in Figs. 8 and 9 the sidereal compass is in one case reproduced as a rectangle and in the other as a circle. The first complete information about the compass was supplied by Sanchez y Zayas (1866, pp. 263—264), and in accordance with the express instructions of the informant the compass was drawn up in the shape of an irregular rectangle. The German ethnographers reproduced the sidereal compass in a similar way. From a practical navigational point of view, however, it does not matter whether the Carolinian navigator conceived of the horizon as a rectangle or as a circle.

It has been mentioned earlier that Altair indicates the east-west axis of the star compass, which means that this axis is correct only at a latitude corresponding to the declination of the star, that is to say, 9° N. If one leaves this latitude and goes north or south the bearing to the points on the horizon where the compass stars rise and set will be changed. The further one goes away from the mean latitude the greater will be the change. In other words the compass will be misleading. However, the directional change is not uniform, but is least in respect of stars which rise and set near the east and west and increases towards the northerly and southerly points. Polaris and the vertical Southern Cross always indicate true north-south, however, and a star with a declination of 0° always indicates true east-west, irrespective of latitude.

As the compass error occasioned by latitude changes increases more quickly on north-south courses than on east-west ones, this means that the compass can be used within wider latitude limits on east-west courses than on north-south ones. For example, if the desired compass accuracy is 1° and the compass course $< 45°$, the latitude area within which the desired degree of accuracy can be attained is about 11° (about 700 miles). (Cf. Frankel, 1962, p. 42.) Courses between 45° and 135°, on the other hand, can be steered for much greater distances.

It is not possible to make a direct comparison between the use of the star compass and that of the magnetic compass. A magnetic compass indicates (with certain corrections) the true course expressed in degrees, irrespective of latitude. On the other hand, the task of the sidereal compass is not to give true bearings but to indicate courses to be steered in relation to known geographical points. Consequently, it consists partly of a fixed number of points on the horizon where stars rise and set, and partly of the positions of the known islands and atolls in relation to those points. If the Carolinian navigator knows that there is another island group a long way outside his own archipelago, and he is aware of its position in relation to the sidereal compass, he can (in theory) reach this group by steering towards the rising or setting point of the star which indicates the course to the island group in question. If, during the voyage, the latitude change has been considerable, the direction to the star's rising/setting points will also have changed and the compass will indicate directions other than those in the Carolines. However, a change in latitude will also mean that certain stars drop below the horizon, while others rise above it. In that case the navigator must therefore replace the stars located towards the poles by new ones, and in addition he must adjust the compass to take account of the fact that the directional change in the rising and setting points of the stars has not been uniform. It is necessary for him to construct a new compass in relation to whose points the relative positions of the islands in the new archipelago are given.

3. *The sun and its motion*

The position of the sun in the ecliptic was given with reference to the constellation it was in at sunrise. The months (varying in general between 12 and 18) were often also named after these constellations. There were local variations in this respect, however. For instance, Krämer says that on Lámotrek the months were instead named after the stars which rise at midnight, that is to say, those which reach their zenith in the early morning (1938, p. 133).

However, the sun's annual motion not only formed the basis of the calendar, it also made possible a reconstruction of the sidereal compass and a checking of the course steered at certain times during the hours of daylight. This was done by observing at which compass point the sun rose and set and by reference to this, determining, first, the compass points of Altair, and then the other points (Eilers, 1935, p. 84).

As the sun's path varies in relation to the stars, its rising and setting points on the sidereal compass will constantly change. The navigator thus had to know where these points were on the compass throughout the year so as to be able to reconstruct his compass with the help of the sun. In his account of the astronomy of the Gilbert Islands Grimble states that the sun's position at sunrise was fixed at 10-day intervals (1931, p. 206). In view of the unanimity of the information from the Carolines concerning both the observations of the sun's annual motion and its importance in navigation, it does not seem altogether unreasonable to assume that a similar periodic determination of the points at which the sun rose was also made within the Carolines. Observations made at such intervals will cause an error in the true bearing to the rising (setting) sun of not more than about 4°. This will happen at the time of the vernal and autumnal equinoxes, when the change in the declination of the sun occurs most rapidly. Around the time of the winter and summer solstices the error is negligible.

The accuracy of the reconstruction of the sidereal compass by means of the rising and the setting sun, as observed at 10-day intervals, can be considered quite adequate for navigation within the voyager's own archipelago. According to Hambruch the course could also be checked when the sun was on the meridian, that is to say, when it reached its maximum altitude. The shadow cast by the mast at that moment indicates true north-south (the compass points for Polaris and the Southern Cross), and the navigator would then have an opportunity of reconstructing his compass and checking his course. (Hambruch, 1912, p. 23.)

4. *Meteorology*

To accomplish a sea voyage, whether long or short, the navigator not only has to know how to steer the intended course, he must also be able to decide, with respect to weather and wind, what is the most suitable period of the year for embarking on a voyage, and also what winds and currents he can expect to meet during the voyage. Owing to the relatively stable weather conditions that prevail within these regions of the Pacific Ocean it is possible for the navigator to forecast the meteorological factors to some extent. Within the central Carolines the year is divided into 18 or 19 periods of varying lengths, based in the main on the helical rising of certain stars or constellations. (These agree only partially with those included in the sidereal compass.) By setting the weather conditions in relation to these stars there has been developed a "navigator's almanac", in which attention has mainly been given to indicating as carefully as possible the time at which the weather changes and those

The Marshall Islands

1. General

The Marshall Archipelago consists of about 28 atolls and four islands lying in two parallel chains, Ralik and Ratak, and extending over 600 miles in a NW—SE direction. The distances between neighbouring atolls within each of the two island groups are fairly short and do not exceed about 85 miles. The greatest distance between Ralik and Ratak is about 130 miles. However, navigation within the archipelago is made difficult by the fact the islets are mostly very low and can be sighted only at short distances, and also by the fact that the main direction of the trade wind and the equatorial currents cuts right across the longitudinal axis of the Marshall Islands. As communications took place mainly within the island chains themselves this meant that while moving along north-south courses the canoe would be greatly affected by wind and current. Ocean currents and local currents are both strong and variable, and this adds to the difficulty of estimating the canoe's displacement.

Navigation within the Marshall Islands, like that within the rest of Oceania, was based on astronomical knowledge. Along with this, however, there was developed a system of navigation that is quite unique. This system is based on a careful observation of the changes in the direction and configuration of the swell and the waves, which come about when these meet the atolls in the archipelago. These changes cause certain characteristic observable phenomena, through which the navigator can indicate the direction to land that is out of sight and determine his position in relation to surrounding islands. The navigators of the Marshall Islands displayed their knowledge of swell and wave phenomena in their widely discussed navigational charts, or "stick charts" as they are often called.

2. Astronomical navigation

In the study of navigation within the Marshall Islands interest has generally been concentrated on the navigational charts and on attempts to interpret them. For this reason our information about the islander's astronomical knowledge and about the way in which the heavenly bodies were used for navigation is rather limited.

Polaris and the Southern Cross, which are visible in most parts of the Marshall Islands, indicate true north-south for the navigator and constitute the fixed points in an orientation system. Erdland states that if these stars were obscured by cloud, the navigator used two other stars, σ Sagittarii and β Libræ, in order to determine north and south. A line drawn through these two stars towards the pole, Erdland adds, would pass through the position of Polaris and in this way indicate true north. (1914, pp. 85, 89.) This statement is incorrect, however. The relative positions in the firmament of these stars are such that a line drawn through them does not by any means indicate north. Consequently they cannot have been used for the determination of direction mentioned by Erdland. His statement must be based either on an incorrect indentification of the stars or on a misinterpretation of his informant's statement. In spite of the fact that this item of information can easily be checked it has been quoted by other ethnographers.

The course was steered with the help of horizon stars, in accordance with the principle previously described in detail in the discussion on Polynesian navigation. When voyaging from one atoll to another the course was usually set from one fixed point or headland to a corresponding point on the other atoll. The course was indicated by stars rising over these points. The navigator knew how long he could steer by such a star before its azimuth change made it necessary for him to replace it by another one. (Erdland, 1914, pp. 80—81.) Erdland has also stated which guiding stars were used on a number of different voyages within the Ralik group. The information is incomplete, in so far as only one star has been allotted for each voyage.

According to Davenport it was necessary for the direction to the steering star to coincide only roughly with the true course. The experienced navigator knew how much he needed to allow for the difference between these, and he also knew how much to compensate for leeway and set and drift with current. (1960, p. 19.)

3. Navigational charts

The existence of navigational aids, known as "stick charts", of a kind that is unknown outside the Marshall Islands, was reported for the first time by Gulick, the American missionary (1862, p. 304). Being, as they were, one of the few examples of primitive cartography they aroused great interest right from the start, and much effort has been devoted to interpreting their true meaning. After detailed field studies the principles on which the charts were constructed and used were explained by Winkler (1898, p. 1418, ff). These investigations were supplemented by Schück, who assembled and analysed information concerning all the chart material then known (1902). Further attempts have been made to interpret the charts, but these have hardly made any essential contribution to our understanding of them.

The stick charts consist of a more or less complex network of sticks (palm ribs) bound together with strings made from coconut fibre. Sea shells and small pieces of coral are often fixed to the sticks in order to represent the atolls of the archipelago. However, the charts are not sea charts in our meaning of the term, because in most cases their main purpose is not to give an exact geographical picture of the island world. The primary aim of the navigator-cartographer is to illustrate swell phenomena in the neighbourhood of the atolls and the positions of the atolls in relation to these phenomena. His interest in the actual distances and directions between the atolls is a secondary one only. Although the principles underlying the stick charts are the same throughout, charts referring to one particular area can vary widely both in scale and in construction. The fact is that the charts are an expression of the personal knowledge and experience of the different navigators, which are kept strictly secret and not circulated outside the immediate family. For this reason a full interpretation of a chart is often possible only with the help of its constructor.

The charts were not taken on board during sea voyages, nor were they used, as western sea charts are used, for laying out courses, plotting bearings or as an aid in identifying a coast. They are, instead, to be regarded as a means of storing navigational information already obtained.

(1) Principles

The phenomena which the navigator observed and which helped him to indicate the position of and the direction to an atoll still out of sight, are the refraction and reflection which occur when a swell meets land. (Cf. Davenport, 1960, pp. 20—21.)

(a) Refraction. As the swell nears land and the water becomes shallower the speed of the inshore ends of the waves is reduced in relation to the offshore part of the swell which is moving in deeper water. The result is that the inshore portion of the swell changes direction and tends to follow the contours of the shoreline. On the lee of the island the change in direction can exceed 90° and give rise to a cross swell. The size of the refraction will depend on the length and height of the swell, the shape of the island and the depth of the sea around it. A strong swell moving towards a circular island or atoll will result in a marked refraction and a characteristically turbulent "shadow", which is noticeable a good many nautical miles out at sea from the leeside of the island.

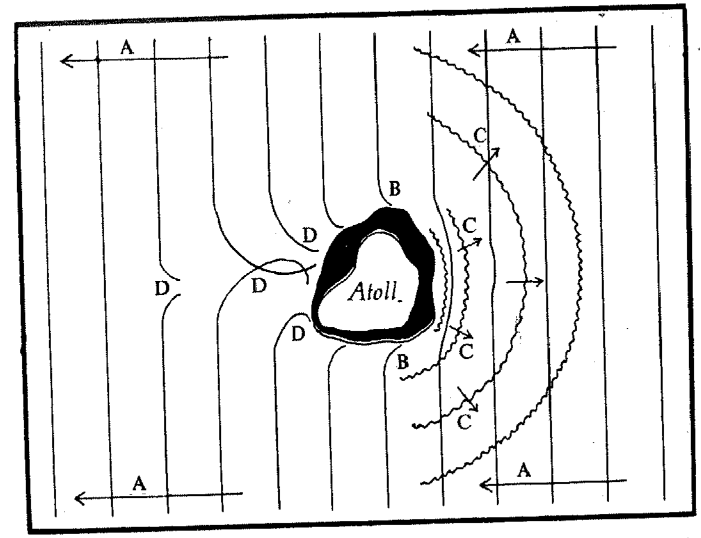


Fig. 10. Refraction and reflection of ocean swell. A, direction of swell; B, refracted swell; C, reflected swell; D, shadow of turbulence. (After Davenport, 1964.)

(b) Reflection. Part of the swell is reflected by the shoreline. These reflected waves differ in appearance and direction from those of the swell.

Within the Marshall Archipelago the swell can be observed from four main directions:

Easterly swell.	The strongest. Can be observed in all parts of the archipelago throughout the year.
Westerly swell.	Weaker than the easterly swell, but can be observed all the year round by an experienced navigator.
Southerly swell.	Weaker then the easterly swell. Mainly to be observed in the southern regions of the archipelago.
Northerly swell.	Weaker than the easterly swell. Mainly to be observed in the northern regions of the archipelago.

The easterly swell and the westerly swell are both divided by an atoll into north and south arms by means of refraction (Fig. 11).

When the northerly (southerly) arms of the two swells intersect at a certain angle the waves become peaked and broken in what is called a *bot* (node). The narrow sector within which the nodes are visible is called the *okar* (root) and extends north and south of the atoll. (It is called *okar* because just as one finds a tree if one follows its roots, so one will find the island on which it grows if one follows the sector

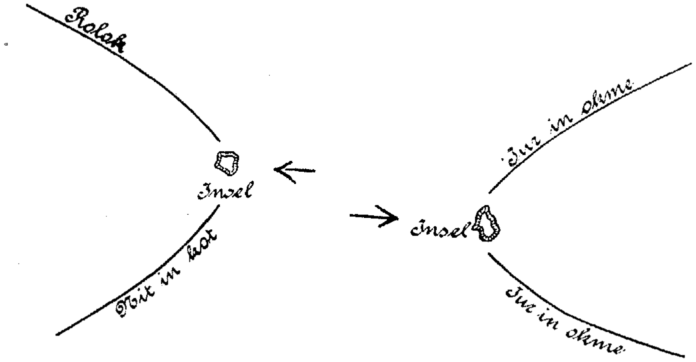


Fig. 11. Refraction (after Winkler, 1898).

where the nodes are seen.) At a certain distance from land the angle of intersection between the swells is at its maximum and it is here the nodes are most in evidence. As one approaches land this angle diminishes, but the refraction increases and with this the extent to which the intersecting swells deviate from their original direction. By following an *okar* and observing the changes in the direction and angle of intersection of the swell, the navigator is able to determine whether he is nearing land or getting further from it. A navigator who has not reached an *okar* can, by observing the direction of the swell, decide whether he is to the north or south of the atoll (Fig. 12).

The northerly and southerly swells can be used for navigation in a similar way.

The Marshall Islands charts can be regarded as models reproducing the phenomena described above. It is probable that certain constructional details on some charts ought to be interpreted as a direction concerning the position from which an atoll could be sighted.

Some ethnographers, mostly German (Krämer and others), have maintained, however, that the charts also contain information relating to the ocean currents. In his pioneer investigation Winkler, on the other hand, has emphasized that this is not so (1898, p. 1422) and his view is also shared by Davenport (1966). There seems to be no reason to object to the views of these two scholars.

(2) Types of chart

The charts fall into three main groups:

Mattang Chart for instructional purposes, designed mainly to illustrate the phenomenon of refraction.

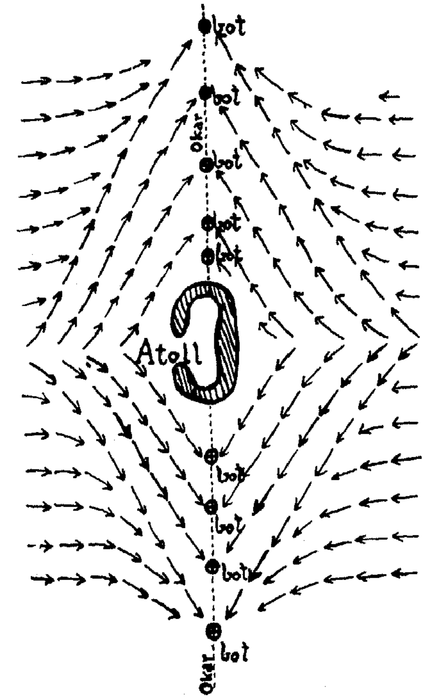


Fig. 12. Bot *and* okar *(after Krämer, 1906).*

Meddo Chart of a certain part of the archipelago. Indicates the relative positions of the atolls and gives certain details concerning prevailing swells.

Rebbelib Chart of the whole archipelago or of one of the two atoll groups Ralik and Ratak. Contains few details relating to the swells.

(a) *Mattang*

The construction and use of the navigational charts is best explained by describing a *mattang*. These exist in a number of different versions, but the one shown in Fig. 13 seems to be a type in more general use and so it has been selected by way of illustration. Various interpretations of it exist, but on the whole these differ only in certain details. Davenport's presentation has been followed in Fig. 13. (1960, pp. 22—23.)

The chart is orientated with reference to the direction from which the dominant easterly swell comes. This direction is indicated by the line (the stick) R^1—R^2.

The chart can be used in order to illustrate the appearance of the swell in the vicinity of one or more islands.

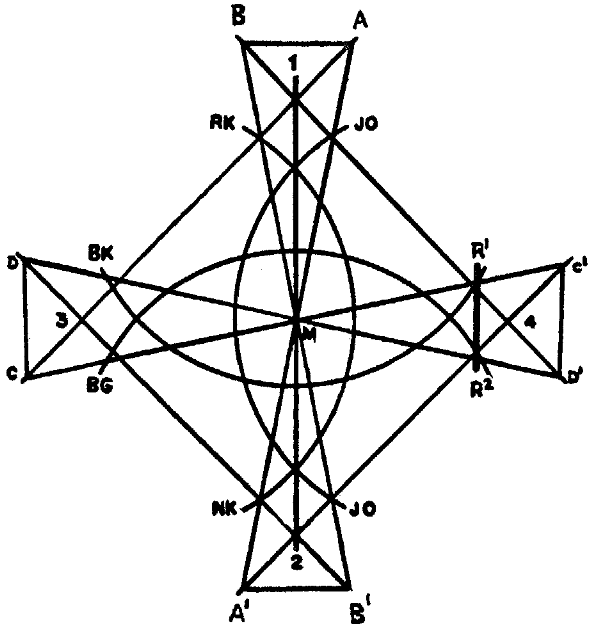


Fig. 13. Mattang *(after Davenport, 1960).*

(i) M denotes an atoll at the centre of the chart.

The easterly swell is refracted in two arms by the atoll M, a northern one, RK, and a southern one, NK. Similarly the westerly swell is refracted in a north and a south arm, both JO. The weaker swells from the north and south are denoted by BG and BK.

When the easterly swell, RK—NK, meets the westerly swell, JO, at a certain angle, the intersecting waves peak and may break, a *bot* (node) is formed. The nodes extend along a narrow sector, an *okar,* north and south from M. The line 1—M—2 represents this *okar.* The nearer one approaches the atoll M along the *okar,* the smaller is the angle between the intersecting swells, and the greater the refraction.

The northerly and southerly swells can be used in a corresponding way.

(ii) The points 1 and 2 represent atolls due north and south of one another. The line AM denotes the easterly swell and the line BM the westerly swell for atoll 1, while B^1—M and A^1—M indicate the corresponding swells for atoll 2. The line 1—2 is the direct course between these atolls and also the *okar* which joins them. A navigator who sails from 1 to 2 therefore follows the nodes in the *okar* from 1 as long as they are visible. He then continues the same course until the nodes in the *okar* from atoll 2 are visible, after which he follows these until he reaches 2.

If a current sets across the course line the navigator compensates for this by following the curved line RK—NK or JO.

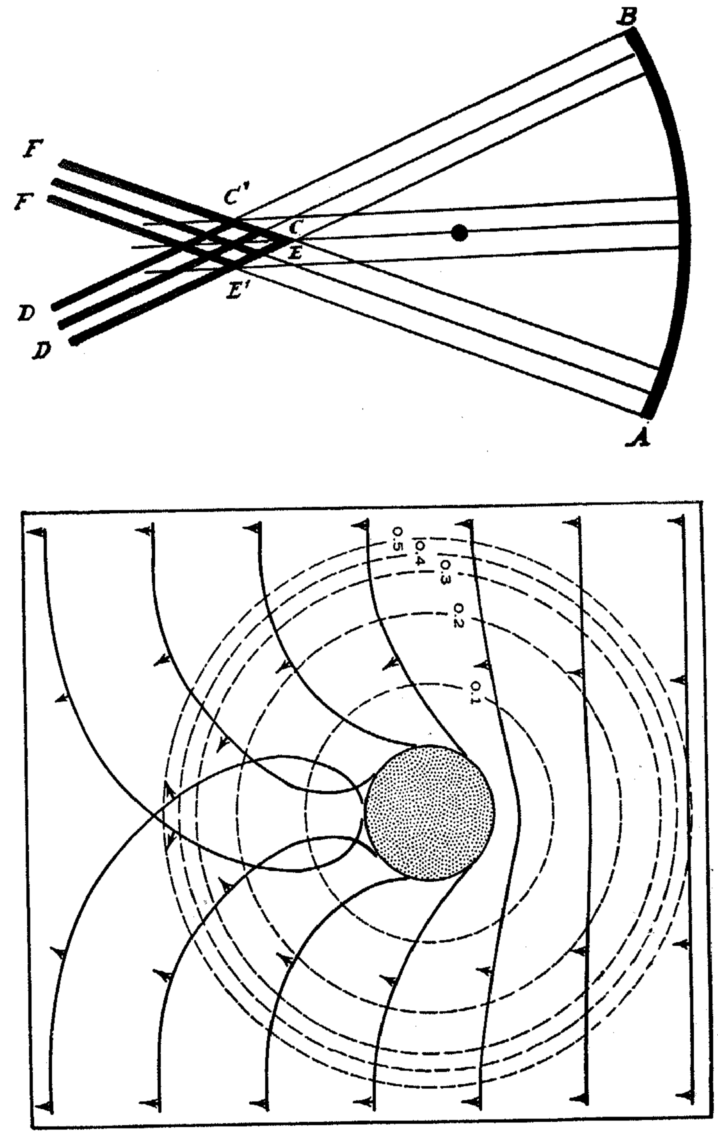


Fig. 14. Mattang *and modern diagram illustrating refraction (after Jeschke, 1906, and H. O. Pub. no. 602, 1939).*

According to Winkler the main function of the sticks CA, BD^1, C^1A^1 and B^1D is probably only to form the framework of the chart, but they could also be used to denote swell (1898, p. 1426). Thus C—1—D^1 gives a northerly swell for atoll 1, and B—4—A^1 an easterly swell for atoll 4, etc.

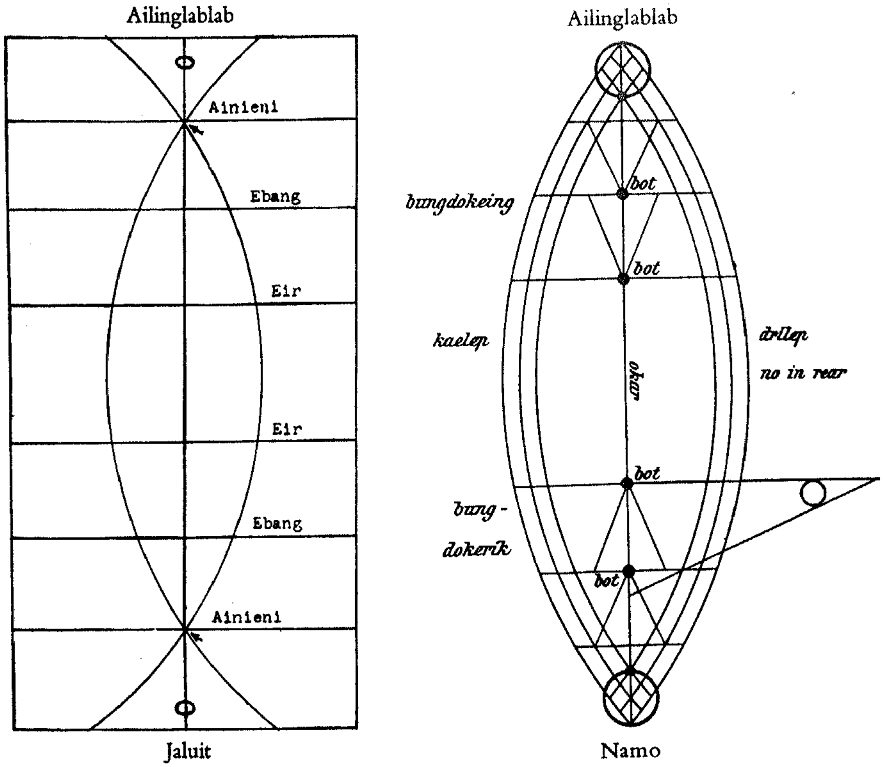


Fig. 15. Meddo *(after Stolpe, 1884, and Krämer, 1906).*

Further variations in the illustration of the phenomena of swell are obtained by allowing the points 1, 2, 3 and 4 to represent four different atolls.

A *mattang* of a simplar type, intended only to represent the appearance of the swell on the leeside of an island, is seen in Fig. 14.

Finely drawn lines indicate sticks which form the framework of the chart. They are of no importance in the interpretation.

The arc A—B indicates the easterly swell, the lines C—D, E—F etc., show how the north and south refracted arms of this swell intersect on the leeside of the atoll. Compare the extent to which this agrees with the same phenomenon as presented theoretically in modern hydrography.

(b) Meddo, rebbelib

The principles underlying the phenomena of swell, which were illustrated by means of the *mattang,* found their application in the construction

of the charts which supplied the actual navigational directions, *meddo* and *rebbelib.*

In the Ethnographical Museum, Stockholm, are one *mattang,* one *meddo* and 16 *rebbelib,* which were brought from Jaluit by Stolpe in 1884. (A further nine *rebbelib* had been found earlier.) Although detailed information concerning these charts is not available it is possible, with one exception, to offer a theoretical interpretation of them by making a comparison with the material published by Winkler and Schück. (Cf. Söderström, 1943, pp. 40—72.) The exception concerns Stolpe's *mattang,* of which it has not been possible to find any equivalent.

A comparison between Stolpe's, Krämer's and Winkler's charts of the same areas is not without interest (pp. 126—127).

Fig. 15 shows Stolpe's *meddo* of the area Jaluit—Ailinglablab (distance between the atolls about 80 miles) and Krämer's *meddo* of the area Ailinglablab—Namu (distance between the atolls about 40 miles).

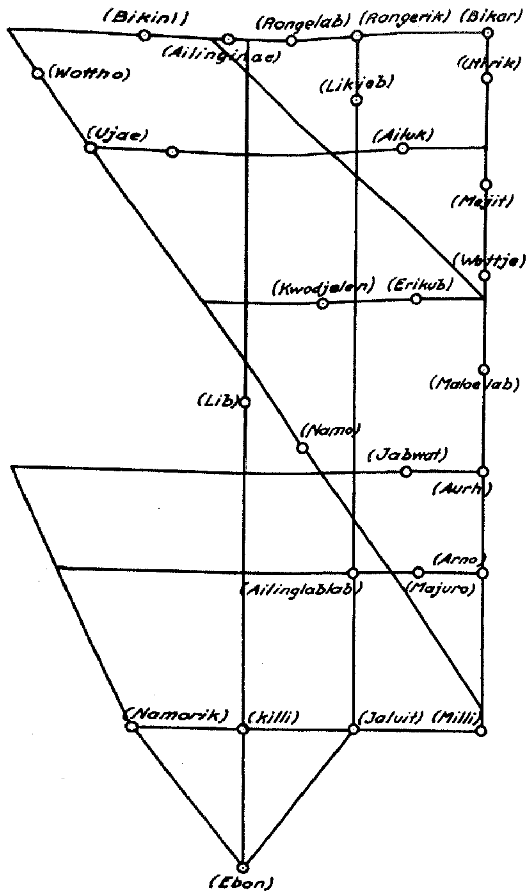
Fig. 16 shows Stolpe's *rebbelib* and one of Winkler's *rebbelib* of the Marshall Archipelago. Of Stolpe's 16 *rebbelib,* 15 are basically of the the same areas is not without interest (pp. 126—127).

The differences between Stolpe's, Krämer's and Winkler's charts are striking and cannot be explained simply by the fact that they were made by different navigators. In contrast to the charts of the other two, Stolpe's charts are so sparsely furnished with details relating to swell phenomena that it can be doubted whether they were of any particular value where navigational directions were concerned. Moreover, on examining his charts one has the impression that most of them are very carelessly constructed, and this cannot be explained merely by the fact that they have deteriorated during the long period they have been preserved in the museum. (This state of affairs, which emerges very clearly from an examination of the whole of Stolpe's material, cannot be illustrated here in sufficient detail owing to limitations of space.)

During his short visit to Jaluit Stolpe was able to secure no fewer than 27 charts. This is a surprisingly large number in view of the secrecy which usually surrounded these charts. It is hard to avoid altogether the conclusion that Stolpe merely succeeded in acquiring a number of "tourist souvenirs", manufactured in haste by a native navigator in order to satisfy an ethnographer on a flying visit. This may seem a harsh judgement, but there are plenty of indications that it is not altogether unjustified:

(i) The defective construction and the poor execution of the charts.

(ii) The large number of charts of the same area, made and owned by one person (at least 15 *rebbelib*). It would be very difficult to supply a satisfactory explanation of why so many copies of a



Stolpe

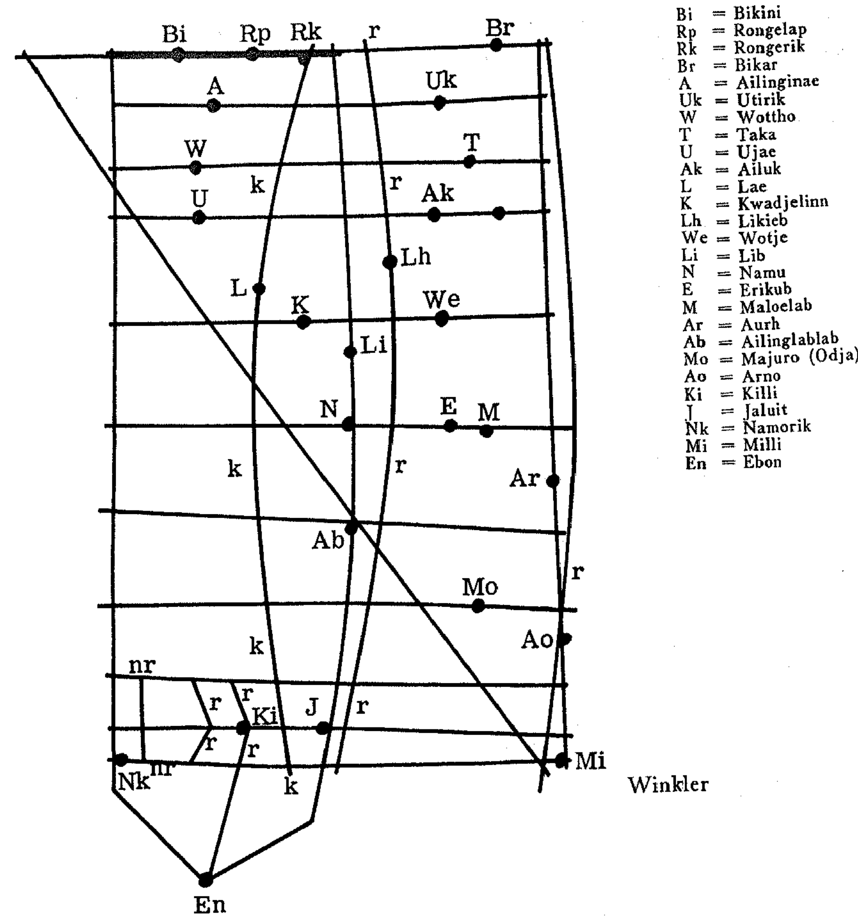


Fig. 16. Rebbelib *(after Stolpe, 1884, and Winkler, 1898).*

secret object were in the possession of one person. By comparison Winkler, who paid at least two long visits to the Marshall Islands, managed to acquire only five charts.

(iii) The instructional chart (*mattang*) was declared useless by one of the acknowledged navigational experts on Jaluit.

(iv) Before and after Stolpe's visit to Jaluit the existence of charts of a much higher quality had been demonstrated.

It appears that, with one exception, the material collected by Stolpe represents an inexplicable down-period in "cartographical" production. When Schück was collecting basic information for his analysis of the charts of the Marshall Islands he wrote to all the museums and institutions abroad whose collections were known to contain such charts, asking for details of these. Stolpe was one of the few who did not respond to this

request. The reason for this is not known, but it is possible that Stolpe realized that his material was not of a kind that could make any substantial contribution to Schück's investigation.

(3) Problems presented by the navigational charts

(a) The distribution of the charts

Most of the known charts seem to originate in the southern Ralik Group, primarily Jaluit, and only a few can be derived from the Ratak Group. It is uncertain whether cartographic representation of swell phenomena was known in all parts of the Marshall Islands. The chart material described by Schück, and including Stolpe's collection, can be traced to Jaluit and Ebon (southern Ralik), Arno and Milli (southern Ratak). According to Davenport the principle underlying this form of navigation, "wave piloting" as he calls it, is still generally known by the navigators within an area stretching from Ebon to Jaluit and Wotje. It is unknown to him whether a similar kind of knowledge is also to be found in the northern part of the archipelago (1966).

There is no confirmation of similar charts having been used outside the Marshall Islands. Information suggesting they had been in existence in the Fiji Islands was convincingly refuted by Schück (1902, p. 33). In the journal *Pacific Discovery* (1952, vol. 5, p. 22) there is a photograph of a stick chart, said in the caption to emanate from the Gilbert Islands. However, the chart is a *rebbelib* of the Marshall Islands, and in appearance and construction closely resembles the type of *rebbelib* described by Winkler and Schück.

In all probability one is on safe ground in saying that the charts represented a system of navigation peculiar to the Marshall Islands. The need for and the requisite preconditions for the emergence of such a system as this also seem to be greater within this archipelago than within other island groups in the Pacific Ocean. The north-south orientation of the archipelago, athwart the trade wind and the equatorial currents, means that the swell phenomena have much the same characteristics in all regions, and can therefore provide the basis for a common navigational system. The short distances from which the atolls can be sighted and the unpredictable displacement owing to wind and strong variable ocean currents meant that orientation by means of heavenly bodies alone yielded extremely uncertain results, even over short distances. Thus there was an obvious need for additional aids to navigation, and the swell phenomena provided the opportunity for the creation of such aids.

(b) The age of the charts

Davenport has advanced the view that navigators in the Marshall Islands had developed their special navigational system, "wave piloting", before their first contact with the Europeans in the 16th century, and that they also knew how to express it graphically in the form of the stick charts (1964, p. 10). He came to this conclusion after a close study of the problems surrounding the stick charts, but he has since pointed out that it is only an assumption on his part and one which is not supported by any definitive data (1966).

The actual existence of the stick charts was not demonstrated until 1862 (Gulick), by which time the Marshall Islands had long been in

contact with Europeans. However, this cannot by any means be taken as indicating that the charts were developed at a late stage. The great secrecy with which they were always surrounded almost certainly meant that for a long period prior to this they had been kept hidden from the Europeans. Severe punishment awaited anyone who made any reference to the charts; "... the individual who first divulged the art to us, though the husband of a chief, was threatened with death" (Gulick, 1862; p. 304).

It is also remarkable that the charts, as has been mentioned above, seem to have had a relatively limited distribution within the archipelago. If they had been of real value in navigation one might have expected the opposite. It is possible that the reason was that the charts soon fell into disuse when the navigators made the acquaintance of Europeans aids to navigation. In any case the apparently limited distribution cannot be taken as proof that they are of late origin. The distribution is no criterion of age.

(c) The origins of the charts

The question of whether the stick charts are an independent invention or the result of a stimulus diffusion, with the European sea charts providing the impulse for their construction, is a much disputed one. Similarly, doubts have been expressed as to whether the charts really could be a valuable navigational aid.

Winkler is hesitant on this point and formulated his views in this way:

> "Meine anfänglichen Zweifeln gegenüber, ob überhaupt so vielerlei Anzeichen berücksichtigt worden seien, und meiner Ansicht, dass sehr wahrscheinlich nur die Hauptdünung, die Rilib, mit Zuhilfenahme der Gestirne die Grundlage für den einzuschlagenden Kurs gegeben habe, wurde, und wohl mit Recht, entgegengehalten, dass dann die verschiedenen Karten mit den vielen Linien und Bezeichnungen doch überhaupt nicht notwendig gewesen seien. Die Existens dieser Karten, die feststehenden Bezeichnung der auf ihnen enthaltenen Linien beweist wohl jedenfalls, dass die durch diese Linien dargestellten Merkmale des Wassers beim Navigieren auch gebraucht sein müssen." (1898, p. 1437.)

Winkler's argument is hardly convincing.

It seems that a more realistic assessment of the problem could be based on the following facts:

(i) The principles underlying the swell phenomena, as these are expressed in the stick charts, were illustrated and explained to Winkler by the native navigators in 1898, long before the Europeans themselves

The Gilbert Islands

1. General

The Gilbert Islands consist of about 16 low-lying atolls and islands which extend for about 350 miles in a NNW-SSE direction. The maximum distance between neighbouring atolls is about 120 miles. The mean latitude of the archipelago coincides with the equator. The minimum distances to the Marshall Islands to the north and the Ellice Islands to the south are about 200 miles. Like the Marshall Islands, the Gilbert Islands lie athwart the trade wind and the equatorial currents, which, however, are not as strong as within the archipelago to the north.

Thanks to the accounts supplied by the late Sir Arthur Grimble, a colonial official who became Governer of the Gilbert and Ellice Islands, our knowledge of Gilbertese astronomy is unusually good (1931, pp. 197—224). On the other hand we do not know much about the way in which the astronomical knowledge was applied in navigation.

Grimble collected his material on the northernmost atoll, Butaritari. Some portions of this are peculiar to this atoll and Grimble was unable to find anything corresponding to it in the rest of the archipelago. It cannot be maintained with certainty, therefore, that the brief account of Gilbertese astronomy given here is valid for all the Gilbert Islands.

2. The celestial sphere

The night sky was regarded as the vast roof of a house running north and south, the observer being by its central pillar. The whole of the astronomical terminology goes back to this concept. The celestial sphere was called, literally, "the roof of voyaging" and the eastern and western horizons were called "the roof-plate of the east" and "the roof-plate of the west", respectively. (Cf. Fig. 17, p. 136.)

The ridge-pole of the roof formed the celestial meridian. The roof was supported by sloping rafters, three on the eastern side and three on the western side, one end resting on the roof-plate, the horizon, and the other end on the ridge-pole, the meridian.

The three pairs of rafters represented the paths of the Pleiades and the stars Rigel and Antares.

The northern pair of rafters met on the ridge-pole where the Pleiades,

declination 24° N, crossed the meridian, while the southern pair had their apex where Antares, declination 26° S, culminated.

Since the mean latitude of the Gilbert Islands is about 0° the celestial equator passes through its zenith, and the declination of a star, when on the meridian, is at the same time its angular distance from the zenith (zenith distance).

The middle pair of rafters, which represented the path of the star Rigel, is said to have formed the Gilbertese celestial equator. As Rige's declination is 8° S this equator lay the same number of degrees south of our own, and also 8° south of the Gilbertese zenith.

On each side of the roof, between the horizon and the meridian and parallel to them, the astronomer imagined there were three purlins (parallels of altitude) across the rafters, an equal distance apart. The height of the heavenly bodies above the horizon was indicated by reference to the purlins, while the sloping rafters made possible a rough estimate of the declination. To allow a more accurate determination of altitude each of the four zones formed by the purlins was divided in two parts. Each new zone thus formed covered an angular distance of about 11°.

On the equator the stars seem to move at right angles to the horizon. The Gilbertese celestial sphere is thus roughly the equivalent of what is called "the right sphere". Its coordinates were: the celestial meridian; the horizon; three parallels of declination (one 24° north of the zenith, two of them 8° and 26° respectively south of it); seven parallels of altitude, 11° apart.

Makemson considers it remarkable that Rigel, at 8° south of the zenith of the Gilbert Islands, has been chosen to represent the central point in the system and its path the equivalent of our celestial equator. The explanation for this, she says, is that the astronomical system originated, not in the Gilbert Islands, but in an area 8°—10° south of the equator, where Rigel passes through the zenith of the observer. Makemson is of opinion that this proves a former connection with the early settlers in New Zealand, for whom *Puanga* (Rigel) was synonymous with zenith. She seems by this to suggest two specific migrations starting from a common homeland, possibly Java or southern New Guinea (lat. 8° S—10° S). (1941, p. 107.)

Owing to the precession of the earth's axis, however, the declinations of the stars is continuously changing. In order to be able to determine the latitude of a migration centre with the help of Rigel's declination, we must therefore know when the migration started, and from this work out the declination Rigel had at that time. If a latitude determination of this sort is to be of any value, it must be assumed that a clearly defined zenith point was included in the astronomical system.

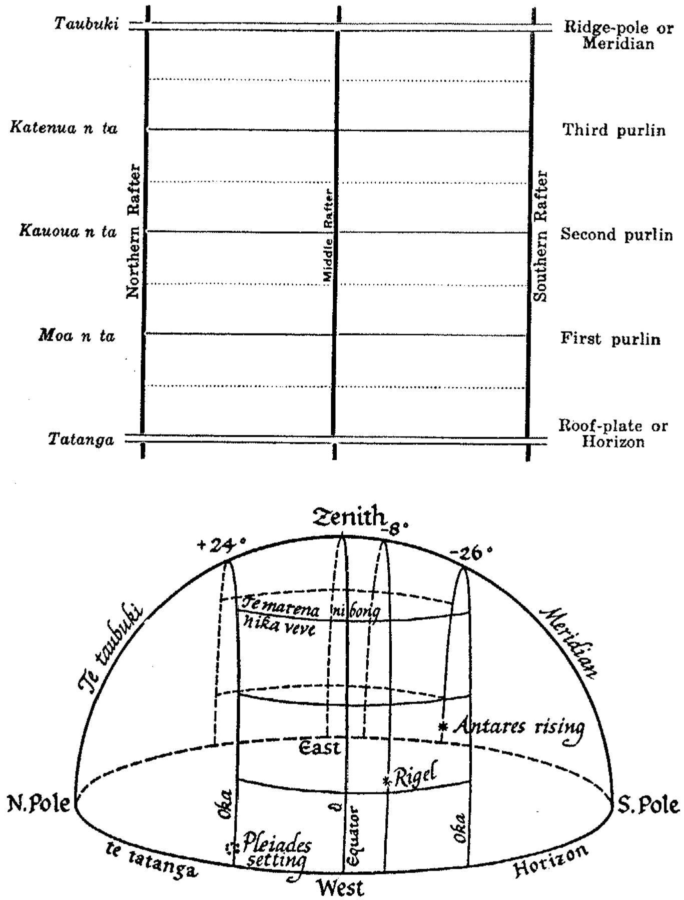


Fig. 17. The Gilbertese celestial sphere (after Grimble, 1931, and Makemson, 1941).

This question has already been discussed in connection with Polynesian astronomy. The point made there was that it is not possible to draw any conclusions of the kind mentioned above by comparing a "primitive" system of astronomy with our own strictly mathematical one, constructed so as to be universally valid. Unlike our own astronomers, the Gilbertese astronomer had no use for an exactly defined zenith or a celestial equator. His system required only a star or a constellation whose path divided the celestial sphere approximately into two halves. Whether this star culminated a few degrees north or south of his zenith made no difference. Similarly, it was a matter of no importance for the navigator.

Makemson's latitude calculation is therefore based on two mistaken assumptions: Rigel's present declination and the concept of the zenith. Consequently her conclusions, too, cannot be accepted.

3. The sun and its motion

The sun's apparent motion to the north and south during the year was determined by observing which constellation it entered at sunrise or sunset. The observations were made at 10-day intervals from a stone platform which gave an unrestricted view of the horizon. The sun was said to have reached a new "station" every tenth day. There were 36 stations (the four cardinal points plus 16 points on the western horizon and 16 on the eastern horizon). Each station had a name and its position on the horizon was known to the navigator. Owing to his knowledge of the direction to the sun at sunrise or sunset the navigator was thus able to check his course at these times of day. Certain of the stations were said to have been named after islands that could be reached by steering towards the points on the horizon bearing their names. On checking this information, however, one finds that in the majority of cases there are no islands corresponding to these points, merely the empty sea. (Grimble has supplied a sketch of the "sun compass" in which the names of the stations are apparently evenly distributed all round the horizon. In reality such a compass can cover only the portions of the horizon where the sun rises and sets, that is to say, an arc of about 23.5° on each side of the east-west axis at the eastern and western horizon respectively.)

Grimble, who has given an interpretation of the sun's station names, considers they are very old, dating back to a time when the language of the Gilbert Islands had not yet reached its present form. He finds support for this view in the fact that in the names of the stations there are words which, while common enough in other Polynesian languages, are no longer used in modern Gilbertese.

One or two of the station names are of special interest:

Te-take: the tropic bird. Could also imply a now forgotten reference to the Marquesas Islands, whose inhabitants call themselves *te-take*.

Makaiao (Maiawa): Said to be a land far to the east reached by seafarers in ancient times. The tradition states that it is not an island but a vast country with high mountains and rivers, which lies further east than all the islands. Grimble asks whether this may not be a folk-memory of voyages to the South American continent, previously undertaken by Gilbertese, though not necessarily from their present area.

Makemson is more categorical and considers this to be a clear reference to Central America; the similarity between Maia in Maiawa and Maya may be more than a concidence (1941, p. 106). The conclusion seems over-hasty. It is not supported by any semantic investigation. The apparent external resemblance between the words tells us nothing about any common background of meaning or about any relationship between them. It should not be overlooked, either, that seafarers from the Gilbert Islands might have visited the American continent on board European ships and their experiences may have been preserved in the form of the tradition.

The lack of agreement between the directions indicated by the station names and the geographical surroundings, as well as the fact that certain of these names are possibly of foreign origin, seems to suggest that this sun compass was not developed locally, but was brought in already perfected by immigrants to the Gilbert Islands.

However, it has not proved possible to demonstrate any corresponding method of indicating direction by reference to the sun's annual motion within either Micronesia or Polynesia.

The solstices and the autumnal equinox were determined by observing the Pleiades, while the vernal equinox was determined by observing Antares. The star's (constellation's) height above the horizon on these occasions was given in relation to the three parallels of altitude (the purlins).

4. *Navigation stones*

On Arorae, the most southerly of the Gilbert Islands, there is a group of eight or nine stones which, according to the information collected by Hilder, formerly guided navigators bound for four islands to the north-west at distances of between 50 and 85 miles. The directions indicated by the stones deviated on average about 5° from the true courses. Hilder regards this deviation as the one required in order to compensate for leeway and current. The stones cannot have served as leading marks, as they are so low that they are soon lost to sight from a canoe. Hilder considers it more probable that, before departure, suitable guiding stars for the voyage concerned were selected by means of the stones, that is to say, stars which set in the direction indicated by the leading line. (1959, pp. 90—97.)

5. *The voyage*

The sailing season within the Gilbert Islands lasted from the culmination of the Pleiades after sunset to the culmination of Antares at the same time of day, in other words from about the end of February or the beginning of March until September. As was the case within other parts of Micronesia the navigator prepared weather forecasts by observing the positions of the stars in the night sky. It was also believed that advance

warning of a deterioration in local weather conditions, which might spell danger to a voyage that was imminent, could be obtained by watching the behaviour of certain animals.

There is an almost complete absence of information about the practice of navigation, though it appears from Grimble's account of a canoe voyage among the islands that the course was maintained by means of horizon stars during the night and the direction of the swell during the day.

Polaris, which was a sure indicator of north within the rest of Micronesia, is not visible from the Gilbert Islands. It is not known whether the navigators knew how to determine north and south with the help of the Southern Cross, though it seems probable that they did.

Owing to our knowledge of the well-developed Gilbertese system of astronomy we know that the heavenly bodies were observed at the transit. Thus it is probable that true north-south was determined when the sun was on the meridian and that the canoe's course was corrected with reference to this. The sun compass also made possible a reasonable accurate check of the course at sunrise and sunset.

The details concerning Gilbertese navigation emanate from the northernmost and the southernmost islands in the archipelago. Corresponding information from the rest of the island world has not been forthcoming. For this reason it is not possible to draw, with certainty, any general conclusions about the navigational methods within the Gilbert Islands. If, as seems likely, regular contacts were maintained at one time between the various atolls of the island group, then it seems probable that the same astronomical system was employed throughout the archipelago. On the other hand, no equivalent of the navigation stones on Arorae has been reported from any other island in the Gilbert group, and so it would appear that these stones should be regarded as peculiar to this island as far as the archipelago is concerned. As previously mentioned, the existence of landmarks arranged in the shape of leading lines or marks to facilitate nautical-astronomical observations has also been demonstrated within Polynesia.