WHO WERE THE BEST CELESTIAL NAVIGATORS?
NAVIGATIONAL TECHNIQUES PUT TO THE TEST!

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From the Editors

Celestial Navigation is the science and art of navigation by the observation of the heavenly bodies—the Sun, Moon, stars, and planets. Widely considered as one of the oldest of human arts, navigation itself has since evolved by leaps and bounds, to what we now know more commonly as radio and satellite navigation. Spanning large distances and often demonstrating pin-point accuracy, modern technology has helped us reach unprecedented levels in the fields of navigation. As our methodology progressed on, many of us have left behind the skill and art of celestial navigation, abandoning it to the winds.

However, it is important for us to learn and to appreciate the fine art that had indeed been the main catalyst for the first meetings of people from different lands. Celestial navigation enabled Man to travel at a monumental scale, to uncover hidden lands and foreign civilizations. This tremendous feat made use of a very simple idea, that at any given time, any particular celestial body will be over a particular geographical location on Earth. This means that it will have an exact latitude and longitude. The actual angle to the celestial object locates the navigator on a circle on the surface of the Earth. Every location on the circle has the same angle to the celestial object, and the circle will be centered on the celestial object's latitude and longitude. Therefore, with the sighting of two or three different celestial bodies, we can plot the intersection of several such circles, hence determining our location.

Celestial Navigation is not an exact science. This holds true especially in the ancient times, where instruments were at times crudely fashioned and charts prone to errors. However, one cannot deny the fact that many have attempted, and succeeded, in crossing vast oceans with nothing but a well-built ship, a despert crew, and a good dose of celestial navigating know-how. Men have staked their lives on it, and through the battles won and lost, we have harnessed this astounding wealth of knowledge that along with it, has brought together a world separated by space. It is in this light that we wish to portray the wonder and awe of the vanishing art that is celestial navigation.

Enjoy the issue!

The Editors
Group 8
The Pacific Islands

Made up of 3 areas—Micronesia, Polynesia and Melanesia, whose territories overlap and intermingle. The majority of these islands are 50-200 miles apart, and the ratio of land to water is 2 to 1000. There is a greater need for sea rovers in Micronesia and Polynesia than in Melanesia, thus leading to more outstanding navigators in Micronesia and Polynesia. Also, there were many inter-island contact patterns.

The Ancient Art

Highly organized navigation systems existed throughout Oceania in pre-European times. This heritage is worth 2000 years. Particular ideas and techniques were favoured in different archipelagos in accordance to local geographical and social factors, but from what was deduced form recorded information, methods were surprisingly homogenous.

There exist various and non-exclusive reasons for voyaging: adventure, as all over Oceania they are very much at ease and at home with the aquatic environment, without intention to conquer, exploring, curiosity, trading ventures, assertion of traditional authorities, raiding, deep sea fishing and the Marquesan custom of voluntary one-way exiles (Porter, 1822) whom are encouraged by priests.
Steering by the Stars

The most accurate direction indicators are stars low in the sky, either just risen or about to set. Navigators steer towards whichever star rises or sets in the direction of the island destination. The bearing of the destination is the azimuth or bearing of its guiding star, at rise if the course is an easterly one and at set if it is westerly. Although stars rise 4 minutes earlier each night, so that after 6 months one that had risen at 9pm will rise at 9am, the points on the horizon where they rise and set remain the same throughout the year. (They vary somewhat with latitude, see sidereal compass)

From the Pacific Islands' standpoint of view, as the earth rotates, we see each star appearing on the eastern horizon at its own special point and makes an arc across the sky. It does not rise straight up the horizon but at an angle, thus if a star rises at north-east, it will change its bearing while moving across the sky and set at its precise westerly bearing—the north-west. Thus a horizon star can only be used to steer for a certain period of time. When it has gone off course, the next star to rise or set at the same point is used as a substitution.

How high a star may rise and still be of use for steering, and therefore how many stars in succession are needed is dependent on the direction of the course and the latitude. While from the equator the apparent motion of stars is vertical, at the south latitudes of the Pacific islands, it is seen to arch towards the north. Firth (1954) states that the star path from Tikopia to Anuta (54 deg) has nine stars, whereas for the passage from Ninigo to Kaniet (dir 80 deg, much east) only 5 stars are needed. (Statement by Itilon of Amich, Ninigo, 1969) Hence each voyage vary in the number of successive stars needed to be completed.

Writing of Tikopian voyaging, Firth (1954) explains that 'the major navigational guide is the star-path, the kavenga of Tikopia, avela by the Tahitians and kaveinga of the Tongans. This is a succession of stars towards which the bow of the canoe is pointed. Each is used as a guide when it is low in heaven; as it rises up overhead it is discarded and the course is reset by the next one in the series...'

The sidereal compass, a slightly more sophisticated concept, in which stars indicate positions around the horizon as well as the bearing of islands. The steering procedure is still the same concept as using the guiding star of an island and succession of stars.

Accuracy in the method is suggested by the most detailed of the early accounts by Andia y Varela who was in Tahiti in 1774. When the night is a clear one they steer by the stars; and this is the easiest navigation for them because these being many (in number), not only do they note by them the bearings on which the several islands with which they are in touch lie, but also the harbours in them, so that they make straight for the entrance by following the rhumb of the particular star that rises or sets over it; and they hit it off with as much precision as the most expert navigator of civilized nations could achieve (Corney, 1914: vol.2, 286)
Caroline-Saipan Voyages

The route to follow is via Pikelot, 100 miles west-north-west of Puluwat. Without instruments, the voyage was undertaken by the Carolinian (Puluwat) navigator Hipour.

The first night was to steer towards the setting Pleiades. But as it was often obscured by clouds, the main direction is maintained by using stars to one side of the rigging—the Great Bear kept in line with the main brace of the starboard beam and the Capella further forward behind the starboard shrouds.

Half an hour later, the Pole star is kept towards the front of the wheelhouse doorway as seen from his position at the wheel (about 20 deg before the beam) and the sinking Pollux fine on the starboard bow. (see diagram below) Pollux set on roughly the same bearing as Pleiades and therefore is a substitution guide for Pikelot.

After Pollux set at one or two in the morning, Hipour continued to steer by Polaris 20 deg before the beam for the rest of the night. Having reach Pikelot in the day, the next destination is Saipan. The course was due north, but because of strong north-east winds, Hipour headed further east than the Pole Star to make up for the leeway—which is in the direction of the rising Little Bear, 10 deg.

It was important and customary in the Carolines to concentrate course adjustments for drifts. Four and a half days later, Hipour altered the course again, this time towards the setting of the Great Bear, so that they might cut the Marianas chain obliquely. That evening land was sighted.

Polynesian double-hulled canoe
Saipan Return to Puluwat using the Sidereal Compass

The geographical course was 164deg, but the course was set to sail south-east towards rising Scorpio to compensate for the current set. After 29 hours the course was altered to Daanup (rising Southern Cross position, 160 deg) but the new track must still have been about 10deg to windward of the direct line, so that not all compensation is made initially. This is a practice of the Carolinians, cramming compensatory course corrections into the first part of the passage.

This return voyage used stars astern and at various angles to the actual course. After dark, with the Southern Crossing not up yet, Venus was used abaft the starboard, and rising Saturn nearly reciprocal to Venus. As the Cross rose towards 45deg, it moved about 10deg to the right and was hidden behind the jib (see diagram) Saturn by then was too high to use for steering and Venus had set, so the Pole Star was held at 20-25deg east of the stern. Antares rose an hour to midnight and as it rose obliquely right along the port as shown in the below diagram, it was used for hours. About 2 in the morning, Altair rose and it was used with the Cross to steer. Before dawn, Saturn sinking in the west provided an additional indicator.
The Sidereal Compass

It is an abstract system of orientation by the horizon points where chosen stars rise and set. All bearings of the stars at rise and set are symmetrical, so that if one rises at north-east, eg. Capella at 45deg, it will set at north-west, likewise 315deg. Hence most of the stars incorporated in the sidereal compass are indicated on two positions, at rise and at set. The exception is the pole star. Due to the south latitudes of the Pacific Islands, if observed at higher latitudes, there exist circumpolar stars such as the Great Bear and the Little bear that do not set throughout the night. The compass works because, although the compass stars which cannot be seen all at one go vary in the time in which they set and rise, at any instance there will be a number of the stars visible. Their function is to indicate points on the horizon’s rim, and these points remain fixed regardless of whether the stars marking them are currently in the appropriate position or not visible at all.

One limitation is that it cannot be used during daylight or when clouds obscure the stars. And since the compass has more densely spaced star markings on the east west plane than the north and south, the validity over the north and south latitudes may not hold accurately, for their azimuths vary most. The frequency of overcast is about one in forty days, and since on those days when the sun is obscured at the desired sight time, the stars often are not obscured in the corresponding nights, hence correction can be made and this does not constitute a major problem at all. Skills vanished under the influence of the technologies of the Western worlds, only the sidereal compass remains unsuperseded by the magnetic compass, because these two are so incompatible.

Subsidiary Directional Guides

Wind compasses note moist and dry winds and the course of cyclones. These varies for different islands from Micronesia and Polynesia. Cook Island’s having 16 points and Tooele Islands 12, with corresponding 16 and 12 names for winds from these quarters, according to where they blow from and the force. Other wind compasses from Sassy and Tonga also exist. But in comparison with sun and star, or ocean swells, winds at best can be secondary indicators.

Sidereal compass know-how, memory of the star sequence and other factors combined made voyaging accurate. Other directional guides are sunrise and sunset bearings, wave swells, phosphorescence, wave refraction pattern and homing birds. These, together with geographical knowledge, mapping, knowledge of the changing waters and the flexibility of changing intended direction to account for currents, leeways—which are sideway wind-drift under sail, and gale-drifts by dead reckoning, account for the precision of navigation. Also, experience and familiarity with the stars plays a part. The Tahitians of 1769 knew a large part of the stars by their names and some know which part of the heavens they are to be seen in any month when they are above the horizon, the time of their annual appearance and disappearance.
Navigational effectiveness in other parts of the world

It is shown that navigators can steer not only by the star in front but also at the side or astern because from it, the direction can be told equally well. This is done by steering to a big star, keeping it at an appropriate angle. This is also the case when weather conditions cause the front star to be obscure, or when it had not risen.

As mentioned earlier on, horizon stars are used when they are low, Hipour’s use of Pleiades when 45deg above the horizon is exception because it was nearly an east-west constellation that was sinking almost vertically. That is the concept of successive stars, because of the south latitudes of the Pacific islands, as the stars move across the sky in an arc, unlike at the equatorial regions.

Hence, in the process of navigation, navigators first know exactly where their destination island lie, then the course of sailing with standard current allowance, then the initial heading to be followed by a variable time and changing depending on leeway producing conditions.

We must also account for the fact that stars move 4 minutes earlier daily. Hence the set of courses considered is only usable at particular seasons. Six months of difference would mean that the stars mentioned appear in daylight, giving rise to different appropriate steering stars for each time of the year.

Hence, to note a drawback, this poses as a hindrance to the collection of star courses. In the Carolines and the Gilbersts, voyaging is in the main season generally from about march or April to September, although voyaging continues through the year in many islands such as Tonga, Santa Cruz and Ninigo. Also, landfall in the daylight is the determinant for setting off time. There is no customary time of departure otherwise.

The use of sun and star steering by eye alone and the use of overhead stars had been proven to be accurate and efficient. The above mentioned clear account of a voyage from Caroline Islands to Saipan Island and back, coupled with many successful voyages tells it all. For example, approximately a millennium ago, Eastern Polynesians migrated to New Zealand, and the navigators returned home with reports of bearings and distances for others to navigate. The fact is, nearly every important navigational techniques and concept matches its Polynesian counterpart. The precision of landfall they achieved were virtually the same. The effectiveness of indigenous navigational methods is undeniable. To date, there remains some Pacific Islanders who possess and practice techniques similar to ancient ones—those that are incompatible with European ones, namely the sidereal compass.
THE POLYNESIANS AND MICRONESIANS
AN INTERVIEW WITH THE MOST WELL-KNOWN PERSONALITY IN ANCIENT CHINESE NAVIGATION — ZHENG HE

As the first intercontinental navigator, as well as the forerunner of mankind’s conquering of the ocean, Zheng He turned the world navigation history from the continent to the ocean.

The number of ships and the loading capacity of Zheng He’s fleets had far outpaced the fleets led by Columbus and Vasco da Gama dozens of years after his last voyage. Zheng He’s fleets were equipped with fore-and-aft sails, stern post rudder and boats with paddlewheels, as well as a compass. Watertight compartments below decks kept the ship from sinking. It was at his time that the Chinese navigation skills reached a high level in terms of geographical navigation, astronomical navigation and navigation weather forecast.

Therefore, in our attempt to learn more about ancient navigation of the various cultures in the world (in this case, the Chinese), we speak to Admiral Zheng He himself to give us more insights on the astronomical aspect of his voyages.

Q In terms of navigation in China, you are not the first, what do you think contributes to your name in the industry?

Well, I would say that my seven expeditions enriched the geological knowledge of the Chinese people and broadened their horizon. Some of my fleet members wrote stories about our voyages, describing in detail the countries and places we have been to, and the local geological situation, religious beliefs, folk customs and weather information. Thanks to their efforts, the public began to know more about the people and culture in Southeast Asia, coasts around the North Indian Ocean, the Arabian Sea and the Red Sea, and the east coast of Africa. It also helps that I adopted a traditional map-drawing method, marking every place we arrived, including all the mountains and rivers, islands and shoals, ports and harbors, cities and temples. In case you did not know about it, I’ve even visited your country-Singapore! Let me show u a navigation map that I drew when I was there.
Q Wow! Could you explain the navigation map that you drew to us?

Certainly[Chuckles]Well, basically this is what I drew when I was in Singapore back then. I entered the Singapore waters through what is known now as the Keppel Harbour. We called it Long Ya men(龙牙门) in the past as there was these 2 big pieces of tooth-looking rock at the place where we entered.

Q Let’s move on to the topic proper. Tell us more about how you navigated through the boundless oceans to reach so many places without the help of modern technologies like Global Positioning System(GPS).

What is GPS? Well, different positioning methods were used in three stages: First from Suzhou, China, to the northern tip of Sumatra in Indonesia, compasses were enough, since the fleet sailed with the coast on its right. The second stage was from Sumatra to Sri Lanka, when the fleet went westward without much change of latitude. In addition, the distance between the two places was relatively short. Compass was the major means of positioning, and celestial observation was employed as an auxiliary method. The third stage was from Sri Lanka to the eastern coast of Africa across the Indian Ocean. A slight digression of the fleet would take it far away from its destination. As a result, terrestrial observation became the only means of positioning. In summary, we depended heavily on 2 very important inventions at that time. Firstly, there was the compass and secondly, there was the star chart. Of course besides these two, we looked at the landmarks along our voyages and also the wind direction for more information.
Q We know that the compass was one of the four greatest Chinese Inventions. But how did it originate in the first place?

Lodestone was found to be magnetic because it attracted metal objects. Another name for lodestone is magnetite. Magnetite is iron ore which is a “rock” embedded with iron. Since lodestone always points in a north-south direction if allowed to freely rotate, a piece of lodestone might have been placed on a section or piece of wood or in a floating bowl. Placed either way, the lodestone would point north. From these applications, the lodestone was used as an early compass.

By the time of the T’ang dynasty (7-8th century CE), Chinese scholars had devised a way to magnetize iron needles, by rubbing them with magnetite, and then suspending them in water (early 11th century). They also had observed that needles cooled from red heat and held in the north-south orientation (the earth’s axis) would become magnetic. These more refined needle compasses could then be floated in water (wet compass), placed upon a pointed shaft (dry compass) or suspended from a silk thread. Consequently, they were much more useful for navigation purposes since they were now much more portable (and smaller). During the Sung dynasty (1000 CE) many trading ships were then able to sail as far as Saudi Arabia without getting lost. The plate was converted to a bowl, and retained the markings of the heaven's plate around its circumference, in a simplified form. The inner circle had the eight trigrams and the outer circle the 24 directions (based on azimuth points).
Q How about the star charts? How did you exactly use the star charts to navigate?

The pole star was of great importance to the Chinese, both symbolically and for navigation. It was the fundamental basis for Chinese astronomy, for the celestial pole was regarded as the heavenly equivalent of the position of the emperor on earth. As mandarins, courtiers and servants circled around the emperor, so did the other stars that rotated around the Pole Star; as the clothes of the servants and their proximity to the emperor signified their importance, the brightness, colour and positioning of the stars were tied to the Pole Star.

By the time I started my voyages, the Chinese had well over 6 centuries of experience of navigation, basing their calculations on both the Pole Star and the stars circling the pole at high altitudes which never rise and never sets. In effect, once we determined the absolute position of the Polaris in the celestial sphere, we ‘tied’ other stars in the Northern Hemisphere to it. When viewing one star or constellation, we knew exactly where the others were in relation to it, even when they had not yet risen in the night sky.

Q Did you faced any problems when using this method?
For one, we could not use the star charts to determine our position in South of the equator where Polaris could not be seen.

Q So how did you measure the distance that you have traveled?
Since we had a rough knowledge of the speed of our fleet, the only problem that we had to solve in order to find out the distance traveled was the time that we had spent on the sea.
One method which was used to measure time was the burning of incense sticks. Simple as it seems, this was a good approximate measurement of time. For one incense stick to burn completely, it would mean that approximately 2 hours has passed.

Q What do you think can be improved if you were asked to review your navigation methods now?
I would say the calculation of longitude [frowns].
Changes in longitude depend on four things, (1) the course steered, (2) the speed of the ship, (3) the time that has elapsed, (4) the distance north or south of the equator
By recording the number of watches, the speed through the water and the compass course, the navigator could estimate the change in longitude.
However, if the body of water over which the ship was sailing was itself moving—when the current is moving with or against the ship—the mariner had no way of measuring the change in longitude and this was one of the major problems that I faced back then. This is certainly one aspect that I would like to see improvement in.

Q Here comes the most important question in this interview. Do you think that you and your counterparts would have been able to navigate effectively in other parts of the world by using your 2 major tools— the compass and star chart?

Well, to answer your question, let me first show you the map of my voyages (marked out in red dotted lines)/

From the map, you can actually see that our voyages were focused mainly in the Northern Hemisphere. Despite of this, I would like to say that yes, I think that my counterparts and I would have been able to navigate effectively in most, if not all parts of the world using our compass and star charts and I have my reasons for saying so. For navigation in the Northern Hemisphere, the star charts and compass would give us adequate information in the general direction that we are sailing towards to. However, navigating in the Southern Hemisphere would prove to be more challenging as the Pole Star cannot be taken in as reference for us to determine our direction as it would not be observable at that angle. In this kind of situation, compass and terrestrial observation would be our only way of navigating.

One of the possible problems that I foresee in the usage of the compass would be when we are in places near to the South/North pole. While the chances are that the magnetized needle in the compass will continue to spin freely and point to North, there is still a possibility the needle would orientate itself along the magnetic lines of forces. If this should happen, the compass would fail in its mission to provide accurate direction to the North. As a result, navigation in the places in close proximity to the south pole would be a problem.
Q One last question before this interview ends. There has been much controversy on whether China discovered America in the year 1421. So it is a fact or a fiction? Young boys and girls, I shall leave it for you to find out. [Grins]

The Ming account of the voyages that followed strains credulity: “The ships which sail the Southern Sea are like houses. When their sails are spread they are like great clouds in the sky.”

Zheng He’s ships as depicted in a Chinese woodblock print thought to date to the early 1700’s
The Ancient Indians

While we explore the history of astronomy and navigation among ancient Indians, we should pay particular attention to sea-faring and the navigation of ships. This is due to the fact that during ancient times, the main mode of transport of cargo and people across the great seas were ships. The ships themselves are also works of one of the greatest engineering ingenuity and technological advancement of their time, but we shall focus more on the navigational techniques and instruments in this article.

The art of navigation was born in the river Sindhu approximately five to six thousand years ago. The very word “Navigation” is derived from the Sanskrit word NAVGATIH.

The Sanskrit word “Nav” - meaning boat, in also the root word I “Navigation” and “Navy”.

History

Throughout the ancient times in India, there were many achievements that can be considered milestones their rich history.

Navigation of ships across oceans were not unknown to ancient Indians. We can find evidence of this within many historical artifacts that were discovered in our modern times. For example, an ancient panel depicting a sailing craft was uncovered in Mohenjodaro. Many millennia later, Ajanta murals were also found depicting sea-faring ships.

The Pali and Sanskrit texts also contain many maritime references, the ancient Indians (mostly from coastal areas), had commercial relations with other countries like Cambodia, Java, Sumatra and Borneo, across the Bay of Bengal. There were even accounts of ties with countries as far as China. Similar maritime and trade relations also existed with countries across the Arabian Sea like Arabia, Egypt and Persia.

According to Romila Thapar, “The trade via the maritime route between the west coast of India and west Asia go back to the third millennium B.C. At that time the Egyptian civilization was in existence and Indus Valley was in its early stages. Once the trade route was established, there was continuous Indian presence in west Asia. This was the predecessor of the trade relations with Rome in the first millennium B.C and Africa in the first millennium A.D.” This further demonstrates the navigational ability of the ancient Indians.

Techniques

There were several different techniques developed in the navigation of ships that did not require the use of a compass, they were mainly knowledge of oceanic currents, weather patterns and migration habits of fish and birds that guided the sailors in their voyages across the oceans. The navigators were also said to be able to detect “magnetic fields in their bodies, thus giving some form of “compass direction”. They could also sense their approximate physical proximity from land.

Instruments

Around 500 AD, the ancient Indians were familiar with instruments such as the astrolabe and compass. Their version of a compass is a pretty simple invention in which a piece of magnetised iron in the shape of a fish, was floated in a container of oil. This of course, would give them the direction of north. This was referred to by the Sanskrit word, “Maccha-Yantra”, meaning “fish
machine”. Another instrument that they used was the astrolabe. This was one of the most ancient tools used to determine a person’s current latitude. The astrolabe will be explained more in detail later.

There was even a version of the sextant, a more advanced instrument used to find the current latitude, used for navigation and this was referred to as “Vruttashanga-Bhaga”. Other instruments and aids include a sundial made out of coconut shell and an interesting invention, “Ra-Palagi”, which is essentially two tiny bits attached to a long string with knots at specified intervals to measure the vessel’s speed at night.

They would also use their hands and fingers to take measurements and refer to “sea manuals” and almanacs to determine various calculations and celestial information.

The Astrolabe

The astrolabe is an ancient astronomical instrument, it was used mainly for determining the locations of stars and the sun, but it could also be used in calculation of local time; given the current longitude or in the case of the mariner’s astrolabe, it was used to calculate the current longitude given the time of day.

Literally, the meaning of “Astro” is star and “Labe” means to take. Together, they refer the the astrolabe as an instrument to take (measurements of) stars. The astrolabe is constructed of several parts, one the main portion being a circular disk (mater), in which one of more plates (tymans or climates) are inserted. These plates are customized for a fixed latitude as the shows the stars in the celestial sphere that is visible from that latitude. Imprinted on it was also lines representing azimuth and altitude.

The rim of the mater is usually divided into hours and/or degrees. Above the mater and tympani, there is a framework (rete) with the projection of the ecliptic and many pointers showing the positions of stars. The rete is free to rotate, and one full rotation is equivalent to the passing of a single day. In fact, the astrolabe is a predecessor of the modern planisphere.

Pictures of ancient astrolabes from the 16th and 18th century respectively
Printed on the reverse face of the *mater*, are scales which can range from a calendar for conversion of day of the month to the sun’s position on the ecliptic, curves for time conversion, or even trigonometric scales. There is also a measurement of 360 degrees on the reverse face. A second ruler, the *alidade* is also attached to the back face and this was used to calculate altitude of stars sighted along its length.

Many historians have debated the origin of the astrolabe over the years, but one thing for certain is that before the invention of the *sextant* in the 16th century, the astrolabe was a main navigational instrument of the Indians. An adaptation, called the *Mariner’s Astrolabe* is basically a simplified astrolabe that tells the user his current latitude, but not longitude. This version of the astrolabe works by having 0 to 90 degrees printed over the four quadrants of a circular disk in a clockwise direction and a free rotating *alidade*.

![Picture showing an ancient mariner’s astrolabe](image)

It is operated by holding to a ring attached to the top of the disk and aligning the *alidade* to the noon position of the sun or any star along the meridian (due north or south) at night. The current latitude would be calculated by looking up the current declination of the sun or star for that current date in an almanac and by using the simple formula:

\[
\text{Current Latitude} = 90 \degree - \text{measured altitude} + \text{declination}
\]

Once ships sailed to the required latitude, they would just go due east or west to reach the desired location. You too can make your own *Mariner’s Astrolabe* from the cut-out in the centerfold of this magazine.
Navigational effectiveness in other parts of the world

What if the Indians did not live in India, but another part of the earth? Or even in the southern hemisphere? We set out to evaluate the effectiveness of Indian navigational methods and instruments. Would they be able to reach their destinations with only the same instruments and skills?

The following is a table to help you understand the tools and methods used by the ancient Indians better.

<table>
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<th>Tools</th>
<th>Uses</th>
<th>Location Based?</th>
<th>Usefulness</th>
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<tr>
<td>Mariner’s Astrolabe</td>
<td>Finding Latitude</td>
<td>Works Anywhere*</td>
<td>Very useful, but only for latitude</td>
</tr>
<tr>
<td>Fish-in-Oil Compass</td>
<td>Finding Direction</td>
<td>Works Anywhere^</td>
<td>Very useful</td>
</tr>
<tr>
<td>Knotted Rope</td>
<td>Measuring speed of ship or boat</td>
<td>Works Anywhere</td>
<td>Moderate, to be used in conjunction with other tools</td>
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<tr>
<td>Sundial</td>
<td>Telling time</td>
<td>Works Anywhere in daylight</td>
<td>Slight, only aids in planning, not much for navigation</td>
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<tr>
<td>Knowledge of Oceanic currents</td>
<td>Navigation across the oceans</td>
<td></td>
<td>These knowledge based techniques would work for the people only if they had prior experience with the same area or the information had been passed to them.</td>
</tr>
<tr>
<td>Knowledge of weather patterns</td>
<td>Wind direction and planning time of beginning voyages</td>
<td></td>
<td>They would all be useful as they aid in the navigation of their voyage at sea.</td>
</tr>
<tr>
<td>Knowledge of animal habits</td>
<td>Aids direction and avoidance of danger</td>
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Note:

*Mariner’s Astrolabe will work anywhere as the plate of the local celestial sphere is not needed as for the astrolabe as it just needed to determine the current latitude.

^Fish-in-Oil Compass is not absolutely accurate as it works slightly different in the northern and southern hemisphere.

In the northern hemisphere, it points to the north magnetic pole (located at the northernmost point of the Artic coast of North America) of the earth and not true north (at the north pole). Whilst in the southern hemisphere, it points to the south magnetic pole (located south of Australia, in Antarctica) and not the south pole.

Another good point to note is that the north magnetic pole constantly moves in about a thirty kilometer radius without a fixed course, while the south magnetic pole does not change location.
After evaluating the different techniques, tools and vast knowledge of the ancient Indians, we have come to a conclusion that the ancient Indians indeed had significantly excellent skills of navigation. That can be seen in the instruments that they had and their usefulness, even if applied in different locations of the world.

Other evidence that the ancient Indians were skilled in navigation were the ancient Indian artifacts uncovered in parts of the world, far away from India. Indian products such as spices, scents, carvings and other items were exported and used in other countries. These shows that the ancient Indians could easily and quickly travel across the seas to and from other countries to trade and sell their products. This further support the conclusion that generally, the ancient Indians were frequent travelers and not just having one particular, individual, good explorer.

Appendix:

Romila Thapar (1931- ) is a historian mainly writing on Ancient India. She secured her doctorate under A. L. Basham at the School of Oriental and African Studies SOAS, London University in 1958. Later she worked as Professor of Ancient Indian History at the Jawaharlal Nehru University, New Delhi.

Accounts of compasses and sextants used 1500-2000 years ago by Mr. J.L. Reid, who was a member of the Institute of Naval Architects and Shipbuilders in England published in the Bombay Gazetteer, vol. xiii., Part ii., Appendix A.
D.I.Y. MARINER’S ASTROLABE
Who were they?

The Phoenician City-states

The Phoenicians were people living on the coast of ancient Syria by 1100 B.C., located at the east end of the Mediterranean Sea. At that time, the Phoenicians were in search of minerals and trade opportunities. They then colonized many areas along the Mediterranean Sea and occupied a cluster of cities known as Lebanon and Syria today. One of their major successes was their establishment of trade within the region. They were also well known for their artistic creations like carved ivories used in furniture, glassware and metalwork.

The Phoenician Alphabet

Later during the seventh century B.C., the Greeks then arrived and established several colonies in southern Spain and along the Mediterranean coast. As a result of frequent interaction between the Greeks and Phoenicians through trade, there were much exchange of not only goods but also techniques in navigation and even the cultural exchange of language – the Phoenician alphabet – which the Greeks then later modified to derive their own set of alphabet.
What's so special about them?

Phoenician Ships

The best seafarers and ship builders of in history were the Phoenicians. To start off with, they had ample resources of ship material – the well-known Lebanese cedar trees covering the mountain forests of their indigenous land was a perfect material for building of robust seaworthy ships. The main concern of Phoenicians then was trade, and therefore their types of ships constructed incorporated features that favoured sea travel and transportation of goods.

Phoenician ships had some similarities with modern Egyptian ships, especially in the structure. However, they were different from Egyptian ships in two major aspects. Firstly hulls of Phoenician ships were shorter and therefore perhaps more seaworthy. Secondly on a Phoenician ship, there would be a wicker fence along the sheer strake to shield the deck load.

1500 B.C. Phoenician merchant ship having strong stem posts, 2 stern oars, and a sail attached to the mast directly. A large clay amphora is secured to the prow stem post to keep drinkable water.

The Phoenicians constructed characteristic round ships that relied primarily on sails and not oars. Due to the broad-beamed feature, the ships had a much larger cargo space. These ships were used for travel even further than the Mediterranean. Usually the upper deck was used to ship
important consignments. The bow was bound with iron to shield the hull in case of collisions or impacts with an enemy ship.

Ancient Greeks, like the Phoenicians, used ships frequently for trade and fishing. Little is known about ancient Greek ships because the wood or papyrus materials that were used to build the ships had very short lifespan. Nonetheless, historical records show that one main difference between Greek and Phoenician ships was that the Greeks, unlike the Phoenicians who were mainly traders, were also concerned with spreading out their territories. Thus, the Greeks constructed ships also as tools for conquest. During ancient times, naval wars involved the collision of enemy ships. Thus the challenge was to construct fast ships, which means many rowers are required, while keeping the ship structure as short and streamlined as possible.

Ancient Greek Warship

The Beginnings of navigation by the Phoenicians and Greeks

The beginnings of navigation dated back to about 5500 years ago, when merchants in the Mediterranean region were transporting enormous amount of goods for trade across seas. Since then, the Phoenicians and Greeks had created advancements in navigation that was useful for many centuries. In particular, the Phoenicians made valuable contributions to the marine knowledge. The puzzling question is, how was navigation possible for the Phoenicians and Greeks then without a magnetic compass or chart?

Lead and Line

The first trick of navigation by early mariners was to stay close to shore and watch out for geographic markers for guidance – a technique known as piloting. Greek historian Herodotus, wrote one such practical but rather time-consuming method, five centuries ago. The procedure was to release a sounding line (a rope with lead weight attached at the end) into the sea on approaching the land and allowing the lead to collect some sediment from the bottom of the seabed. If sediment was collected, then the depth of the sea (equivalent to the length of the line immersed into the sea) was approximately the same to the distance the sediment was eroded by the stream (equivalent to the distance to shore). Measurements were counted in fathoms, each fathom being 6 feet long. Every fathom of length was marked on the rope. In addition, the sediment collected could help the sailor make an educated deduction of which region the ship was in by matching with records listing in the Nautical Almanac. The Phoenician sailors frequently
used this method. It was a rather accurate gauge for the sailors to find out how far they were away from the coast.

A simplified picture of a lead and line used in ancient navigation.

Sun Movements During the Day

If the mariners had to travel further out into the open waters during the day, they could watch the height of the Sun to make estimates of the time. The position of the rising and setting of the Sun tells the direction – generally the Sun rises in the East and sets in the West. The midday position of the Sun and the shadows it cast served to divide the east from the west generally. The Phoenicians observed the Sun’s motion, which gave them their directions, which they called Asu (sunrise – east) and Ereb (sunset – west), names known today as Asia and Europe. Early Greeks also distinguished the east from the west using the Spring and Autumn equinoxes when the days and nights are equal length and when the Sun rises exactly at the East and sets exactly in the West.

Celestial Navigation by Night

When traveling at night, the Greeks and Phoenicians lit bonfires along the shorelines for guidance. Furthermore, they used other heavenly bodies like the stars, moon and planets for guidance. Some reports state that the Phoenicians were the first to use the Pole Star (which remains in a fixed position above the North Pole) for navigation and they were the first to circumnavigate Africa.

The Pole Star in those days was more than 12° away from the North Pole, and did not attract much attention. It was another star, known as Kochab today, which was the nearest bright star, at about 7° away from the North Celestial Pole, that was used as a marker for North at night. To an ancient Greek observer who makes no accurate measurements without instruments, the circumpolar Kochab would appear to be in about the same position in the sky every night. However, it was not very accurate because every year it moved some seconds of arc further off due to precession. The Earth undergoes a full precession cycle in about 25,800 years, and in the process the declination and right ascension values of stars will gradually change. Over this cycle the axis of the Earth goes through precession due to the Earth’s oblate spheroid shape (wider at the equator) and the gravitational tidal forces of the Moon and Sun. Therefore, by AD400, Kochab
was 10° away from the North Pole. Gradually, as the Pole Star ‘moves’ towards the North Celestial Pole, Greek writers gave credit to the Phoenicians for teaching them to identify the North using the Little Bear (Ursa Minor) constellation instead, and error in judgment was reduced. In Greek, the word for ‘Bear’ was ‘Arctos’, which also meant North. Today, the altitude of the Pole Star can give an accurate answer to the observer’s latitude. For example, an observer in the Mediterranean region of latitude 39°00′N would be able to see the Pole Star at an altitude of 39° at night.

The night sky diagram showing the changing positions of the circumpolar stars between 1000B.C. and today. (a) 1000B.C. (b) A.D.1 (c) A.D.1000 (d) A.D.1955
The changing path of the North Celestial Pole due to precession resulting in a changing North Star.

Dead Reckoning

The Mediterranean mariners also used a method known as *dead reckoning* to keep note of a ship’s course, speed and travel time to find out position. The general direction and distance traveled by the ship in a day would be measured from a specific point by a navigator, as precise as he could. Travel time was calculated using an hourglass, speed gauged by watching seaweed drift by the ship, and the ending point would be the starting position for the following day’s measurements. Through educated and intelligent guesswork, dead reckoning is usually very accurate. The concept is still being practiced on ships and aircraft. As errors usually get increasingly significant in dead reckoning, its accuracy depends greatly on the use of reliable tools, the length of the journey and the navigator’s capability to use latitude and other information to reduce errors.

Winds

In Mediterranean world, mild breezes that bring rain came from the west (*Zephyr*), while winds from the east felt dry and cool (*Apeliotes*) generally. Close observations reveal that the wind directions could be further differentiated when the directions of the winds are combined (eg. North-East). Thus there was an eight-fold wind direction system derived, later called the wind rose, which further helped in navigation.
Pilot-books

The Greek and Phoenician colonies all over the Mediterranean and Black Seas, and even neighbouring areas of the Atlantic, were evidences to show that they had established a comprehensive circumnavigation of the whole area. They created their first pilot-book, The *Periplus of Scylax of Caryanda* which starts at the mouth of the Nile and advances westwards to the Libyan Coast. The second pilot-book created, *Stadiamus of the Great Sea*, also follows the same journey, but in greater detail and precision. In both books, there were no accounts of the compass.

Navigational effectiveness in other parts of the world

The Greeks and Phoenicians adopted navigational methods that were generally not reliant on instruments and could mostly be carried out accurately in other parts of the world. The lead and line and dead reckoning methods, although time-consuming and involves a lot of patience and experience, could be used rather effectively to navigate in other parts of the world, including regions from the Southern Hemisphere. The limitation to these two methods, however, is that the error becomes increasingly significant as the journey lengthens, and without very accurate equipment, it is difficult to estimate quantities of distances and speeds accurately. Towards more modern times, more precise and sophisticated tools were used to increase accuracy.

The method of observing the motion of the Sun could also be employed in other parts of the world since the objective is to distinguish the general directions of East and West. In all parts of the world, the Sun will still rise at East and set at West generally. At regions at the equator, the Sun will rise above the horizon at East generally and follow a perpendicular path from the horizon at East, continues directly overhead, and sets at the horizon at West generally. The main difference between other regions above the equator in the Northern Hemisphere and regions below the equator in the Southern Hemisphere is in the path of the Sun across the day. In the Northern Hemisphere, the Sun rises above the horizon at East, travels towards South, and sets below the horizon at West. Whereas in the Southern Hemisphere, the Sun rises above the horizon at East, travels towards North, and sets below the horizon at West.

A diagram of an example of what an observer would see of the Sun’s path across the day in the Northern Hemisphere during winter. In the Southern Hemisphere, the Sun travels to the North instead.
Celestial navigation by stars and other heavenly bodies will be markedly different in other parts of the world in the era of ancient Greeks and Phoenicians. Regions near the equator and in the Southern Hemisphere would not be able to see both the Kochab and Pole Star since both celestial markers are only visible from the Northern Hemisphere and were not directly above the North Celestial Pole in those ancient times. Celestial navigation in other regions of the world then would most probably be based on other celestial bodies or markers. Similarly, navigation by wind characteristics and directions would be different outside the Mediterranean region as wind movements are different in various parts of the world due to the Earth’s rotation and tilt. The basis of navigation by wind in ancient Mediterranean cannot be applied in other parts of the world.
Who were they?

The name Viking is a borrowed word from the native Scandinavian term for the Norse warriors who raided the coasts of Scandinavia, the British Isles, and other parts of Europe from the late 8th century to the 11th century. This period of European history is referred to as the Viking Age. The term Scandinavian itself refers to the countries of Norway, Sweden and Denmark.

What was so special about them?

To really understand how special those fuzzy-beard sprouting fellows are, we have to study Europe during the period between 793 A.D. and 1066 A.D, otherwise known as the Viking Age.

So, what happened during the Viking Age?

During this period, the Vikings, Scandinavian warriors, leidangs, and traders, raided, and explored large parts of Europe, the Middle East, northern Africa, and even reached North America. This was the time when Norse influence was spread far and wide into different parts of the world.

To account for the exceptional outreach of the Vikings in the medieval setting, we have to understand some of the factors that had enabled them to do so.
1. It’s the beard, really

Popular culture has always portrayed the Vikings as unruly barbarians that kill and pillage at every chance. While only partly true, it has instilled fear amongst the many who reside within close proximity. Here we explore a few interesting myths about our sea-bound adventurers.

Now in any picture you see with a Viking on them, they will surely be wearing a horned helmet. Some caricatures also depict Vikings using human skulls as drinking vessels. Sometimes, the Vikings are also accused of taking less showers than needed. While a certain underlying notion of machismo has being effectively portrayed here, we have found that the above mentioned are but myths that bear no truth in them.

It is unlikely that the Vikings on any occasion wore horned helmets. Apart from two or three representations of helmets with protrusions that may be either snakes or horns, we have got nothing else. Till today, no one has found a preserved helmet with horns. The idea of horned Viking helmets is, rather, a latter-day myth created by national romantic ideas in Sweden at the end of the 19th century, notably the Geatish Society, incorporating the Viking Age with bits of the Nordic Bronze Age, which occurred 2000 years earlier for which actual horned helmets, probably for ceremonial purposes. Nevertheless, the horned helmet never left the Viking head in print.

The use of human skulls as drinking vessels is also an unhistorical fallacy. The rise of this myth can be traced back to a mistranslation of an Icelandic kenning. In the Latin translation of the Krákumál by Magnús Ólafsson (in Ole Worm's Runer seu Danica literatura antiquissima of 1636), warriors drinking ὀρ ὄροι θηρίων ἐκ τῆς κεφάλας [from the curved branches of skulls, i.e. from horns] were rendered as drinking ex craniis eorum quos ceciderunt [from the skulls of those whom they had slain]. (Scandinavian skalle: skal means simply "shell" or "bowl"). The skull-cup allegation has some history also in relation with other tribes. The Scythians, for example, are reported by Herodotus and Strabo to have drunk from the skulls of their enemies.

Vikings as depicted in popular culture. Source: allposters.com

The image of frizzy-haired, dirty hordes of unkempt barbarians, sometimes associated with the Vikings in popular culture, is also a readily accepted myth. In fact, the Vikings used a variety of tools for personal grooming such as combs, tweezers, razors or specialised "ear spoons". In particular, combs are among the most common artifacts from Viking Age graves. Well surely we can see that a comb was the personal equipment of every man and woman. The Vikings also used soap, long before it was reintroduced to Europe after the fall of the Byzantine Empire. The Vikings in England even had a particular reputation of excessive cleanliness, due to their custom of bathing once a week (as opposed to the local Anglo-Saxons).
While the typical myths are being dispelled, let us not forget that the Vikings DID raid and pillage and pretty much conquered everything in their path. A quick glance at the charts will show the tremendous extent of their sovereign over the Northern Hemisphere.

2. Long ships

The Vikings sailed in the then technologically superior longships, for purposes of conducting trade, however, another type of ship, the knarr, wider and deeper in draught were customarily used. They were expert sailors, adept in land warfare as well as at sea, and they often struck at accessible and poorly defended targets. It is the effectiveness of these tactics that earned them their formidable reputation as raiders and pirates.

Besides allowing the Vikings to travel vast distances, their longships gave them certain tactical advantages in battle. They could perform very efficient hit-and-run attacks, in which they approached quickly and unexpectedly, then left before a counter-offensive could be launched. Because of their negligible draught, longships could sail in shallow waters, and that enabled the Vikings to travel far inland along the rivers. Their speed was also unprecedented for the time, estimated at a maximum of 14 or 15 knots. Sadly, the use of the longships ended when technology changed and ships began to be constructed using saws instead of axes. This led to a lesser quality of ships. By the 11th and 12th centuries fighting ships began to be built with raised platforms fore and aft, from which archers could shoot down into the relatively low longships. This effectively ended the longships formidable run.

3. Superb sea navigating skills

Perhaps the most important factor of all. The Vikings were able to go so far as they did only because they were able to sail the furthest. Backed up by sound navigation techniques, and coupled with immense experience handed down through generations of seafaring, the Vikings clearly showed complete confidence in their navigation techniques. Here we explore the various ways the Vikings found their way around a good part of the Northern Hemisphere.
How the Vikings navigated

The Vikings never had good fortune to be able to use a compass. Instead, they relied on tools from nature to assist them in their navigation. Observations of the sun and Pole (North) Star, currents, winds, and migratory whales and birds were clues for direction. For locating their proximity to land, the Vikings analysed the depth, smell and taste of water. Elements like the cumulus clouds, reflections on the sky, and land birds like the raven were also exploited. What they would do was to release a raven from the ship to see if it could find land, then follow it. The Vikings also left marks on their masts to view against a star. Later if the same star lined up with the mark, they would know they were along the same latitude.

The Vikings were the first known people to use the keel, which was necessary to keep a stable course when they crossed the oceans. Their sailing route was between the 61st and 62nd degree north on a due western course from Norway to Greenland. We can read their sailing instructions in one of the sagas. In the saga Landnámabok it says: "From Hernam (near Bergen) in Norway you must hold on to a due western course, and that will take you to Hvarf in Greenland. On your way you will come so close to the Shetland Islands that you can just see them in clear weather. And you will sail so far from the Faroe Islands that you will see half of the hills in the water. And you will be so close to Iceland that you will see whales and birds from there."

It would seem that celestial navigation by the Vikings did not stray outside the confines of using Polaris. The reason has a lot to do with the location of the Scandinavia in the upper part of the Northern Hemisphere. To explain, towards the more northern parts of the Arctic Circle, there is continuous daylight for months in the summer. And even at 62 degrees north, there are very few stars in the middle of the summer. Therefore, the Vikings used the Sun as their main tool to circumnavigate the world.

Equipment

As we have established, in the North of the Arctic Circle, there is continuous daylight for months in the summer. Since the Vikings voyaged mostly in the summer (especially around the summer solstices) where there are very few stars, they did not rely much on the stars for navigation. Instead, they looked at the sun.

Well surely they did not just stare at the sun and figured out where to go. Here we shall take a look at two more of the more prominent instruments that the Vikings used as navigation tools.

1) Sun Compass

The magnetic compass was used only from the 12th Century onwards. Before then, there was only one navigational reference when sailing across the open ocean at night. Polaris was widely used. In the day, the Sun was used. The problem was, the Sun was not a stationary reference point. It moved. Since the Middle Ages, many long voyages were made by first sailing north or south to the latitude of the destination, and subsequently sailing due east or west to the nearest landmark. The ship’s latitude could be determined by measuring the maximum elevation of the sun (at noon) and knowing the sun’s declination (which varies during the year). At night, the ship’s latitude could be determined more directly by simply measuring the elevation of Polaris. Sailing directly from point to point was, of course, a quicker method, but it was much more complex. Some convenient technique for determining the heading of the ship periodically during the day was needed. If the orientation was left uncorrected, the accumulated errors in
course caused by the constantly changing winds and currents could result in the ship missing its destination.

So how did the Sun Compass work? Basically we have a board with a pin in the middle. The pin in this case is termed the gnomon, and the gnomon will cast a shadow on the board when you put it out in the sun. Now, if we trace the path the tip of the shadow of the gnomon makes in a day, we will see that the length of the shadow will be the shortest at noon. This is simply because at noon, the sun is neither in the East nor West. Rather, it is smack right in the middle. However, due to the declination of the Sun, the Sun will sway a little to the South. The little bit of the shadow we see will be pointing North. From there we can find out where North is.

While shortest-shadow readings from the post will indicate true north, the angular readings along the side of the disk, when compensated according to a certain formula can indicate the distance traveled to north or to south from home port. The changes in length of noon-shadows are also indicators of distance, but are much more difficult to calibrate.

Each sun compass was probably specific to its home port and to its owner. While many disks might have been similar, the center posts were probably different. In order to be reliable, each compass should have been used at home port for at least a year where marks denoting the gnomon's shadow at solstices and equinox could be etched. Further speculation includes that a home-port sun compass was maintained at each city and that permanent sun compasses were established at destination locations. These would be useful in resetting each sun compass.

Therefore, coupled with the experience of the seamen (prevailing wind patterns, migratory birds' habits, wave patterns, shadow patterns), the sun compass truly aided the Vikings tremendously in getting around.

The bearing-dial from Uunartoq Fjord placed in a compass-card of today, divided into both compass points and 360 degrees. The straight line passing through 82 degrees and 278 degrees in the modern compass card is the line followed by the sun's shadow at the equinoxes, also marked on the find. If the notch number 13A was removed deliberately, the division of the bearing-dial is correct within 15 degrees.
2) Sun Shadow Board

The solskuggerfjol (sun shadow board) was used for determining latitude. It was a circular wooden board about 250 to 300 millimeters in diameter. In the center was a gnomon, the height of which could be set to the time of the year. To keep it level, the board was placed in a bowl of water. The shadow of the noon sun was observed. A circle on the board gave the line the shadow should reach if the ship was on the desired latitude. If the shadow was beyond the line the ship was north of this latitude; if inside, the ship was south of it.

Source: http://www.griffithobs.org/IPS%20Planetarian/IPSViking.html
Accuracy

The nautical achievements of the Vikings were quite exceptional. For instance they made distance tables for sea voyages that were so exact that they only differ 2-4% from modern satellite measurements, even on long distances such as across the Atlantic Ocean.

Navigational effectiveness in other parts of the world

So, could the Vikings have conquered the world? Well, assuming that they all the muscle, spinach and ships to go all the way, we shall now try to figure if their navigation technique could have brought them to every part of the world.

Now, from the previous chapters we have come to know that the Vikings relied more on the Sun as a navigational tool. We also know that the Vikings never left the Northern Hemisphere. Therefore, the questions we should ask ourselves should be;

1. Could they have sailed as effectively as they did in the Southern hemisphere?

Since they used the Sun excessively for navigation, our next question would naturally be;

1. How different is the Sun in the Southern hemisphere?

Let us first try to analyze the sun in the Northern Hemisphere

The Northern Hemisphere is basically the half of a planet's surface that is north of the equator. On Earth, the Northern Hemisphere contains most of the land and population. In temperate and polar regions of the Northern Hemisphere most of the year, the sun passes from east to west in the south, causing sun-cast shadows to turn clockwise through the day. In the tropics, the noonday sun is always virtually overhead, but will sometimes be in the south and sometimes in the north.

The Southern Hemisphere is basically the half of a planet's surface that is south of the equator. In the Southern Hemisphere the sun passes from East to West in the North. This generally causes sun-cast shadows to turn anticlockwise through the day.

There are a few major differences between the Hemispheres.

1. The first is the obvious six-month difference in the seasons. When it is Midsummer in the Northern Hemisphere, the South is celebrating Midwinter.

2. The next major difference between the Hemispheres is the direction in which the Sun moves across the sky. As in the Northern Hemisphere, the Sun still rises in the East and sets in the West. However, on its journey across the sky in the Southern Hemisphere, it travels via the North because of the tilt of the Earth's axis.

3. Another difference that is good to know is the direction in which the crescents of the Waxing and Waning Moons point at the two different hemispheres. In the Southern Hemisphere, the Waxing Moon in the sky actually points to the right, while the Waning Moon points to the left. Therefore the symbol of the Triple Moon Goddess (the maiden, mother and
(crone) reflects an introverted appearance opposed to the extroverted appearance in the Northern Hemisphere. But there are times where the Waxing Moon can be observed lying on her back pointing upwards, and the corresponding Waning Moon pointing downwards.

From points 1 and 2, we can see that the seafaring capabilities of the Vikings would most probably be as effective in both hemispheres. The only difference would probably be

1. They would most probably set sail during different parts of the year, because of the 6 month difference in the seasons.
2. As Summer in the Northern Hemisphere is said to be longer than that of the Southern Hemisphere, the expedition period per year for the Vikings would most likely be shortened.
3. Following point 2 from the previous paragraph, we would assume that some of the navigation equipment might need to be recalibrated with respect to the Southern Sun.
4. Should the Vikings really circumnavigate the globe, they must be certain of the location of the equatorial line. This is because the sun compass and the sun shadow board helps in determining latitude, and it can be clearly seen that the numerical latitude values in two exact sides of both hemispheres can be similar in magnitude but different in direction (e.g. 65 North vs 65 South). Therefore, in using either of the instruments in the Southern Hemisphere, the Vikings would probably have to turn the sun shadow board 180 degrees.
5. The Vikings will not be able to sail at night, because Polaris would no longer be visible from the Southern Hemisphere. They can always track another star, but for the sake of this argument, we will assume that they are not able to do so and thus will have to stick to navigating by daylight.
6. The Vikings would need to shave off their beards cos it’ll get too darn hot in the tropics

Should the follow suggestions be fulfilled, it is likely that with adequate time and preparation, circumnavigating the globe would be a possibility.
The Sextant

A sextant is a measuring instrument used to measure the angle between 2 objects, in this case, the angle of elevation of a celestial object above the horizon. The sextant's name came from the fact that it covers one-sixth of a full circle. The octant is a similar device with a shorter scale, that is, one-eighth of a circle. It was in use until 1767 when it was quickly replaced by the sextant.

History

Sir Isaac Newton invented the principle of the doubly reflecting navigation instrument. But because he did not publish it, it was only until 1730 that it was rediscovered, separately by John Hadley, an English mathematician, and Thomas Godfrey, an American inventor. After which it replaced the astrolabe as the main instrument for navigation because it is much more precise, being measured relative to the horizon rather than to the astrolabe.

The octant is limited in its usage when the angle to be measured is larger than 90°. For example, if the angle between the sun and the moon is at times larger than 90°. Navigators use this to find the current time, with lunar distances. Also, when there is a change in temperature the arc may warp, creating inaccuracies. Hence construction of sextants made of a special low-expansion steel, low expansion brass or aluminum, quartz or ceramics started to prevent this problem.

Methodology

The sextant uses the theory of using a beam of light that reaches the horizon as the measuring pointer. The measurement is thus limited by the angular accuracy of the instrument, and whether the user is on a moving ship is of no consequence. The horizon and celestial object remain steady when viewed through a sextant because the sextant views the horizon directly, and views the celestial object through two opposed mirrors that accounts for the motion of the sextant by subtracting it from the reflection.

Since 1 minute of error is about a nautical mile, the best possible accuracy of celestial navigation is about 0.1 nautical miles. This is about 200 yards, well within visual range.

Navigation by Sextant

Celestial navigation using a sextant is an involved process that involves a fair amount of calculating, correcting, referring to tables, knowledge of the heavens and the Earth, as well as a lot of common sense.
How to use a sextant

1. Place your eye at the eyepiece, if there isn’t one, look straight at mirror A from the position of the eye piece. Capture the horizon on mirror A.

2. Rotate the movable arm till you see the celestial body on the horizon. This happens because light from the objective celestial body reflects off mirror B (see above diagram) and is captured on mirror A. Since mirror B is attached to the arm, in moving the arm, at a position, the celestial body’s reflection off the mirror will also reflect off mirror A and through the eyepiece. Hence what you see is actually a merge, or superimposition of the celestial body on the horizon.

3. The angle between the two objects is then read off the scale for the angle between the horizon and the celestial body.

How to read a vernier scale:

In the scale to the left, the index reads 76° with minutes between 20' and 40' (tick A). In the vernier, match exactly the vernier and index scale. Here, the 6th vernier tick matches exactly the index tick, so the reading is 76°26'.

After a sight is taken, it is reduced to a position by following any of several mathematical procedures. The simplest sight reduction is to draw the equal-elevation circle of the sighted celestial object on a globe. The intersection of that circle with a dead reckoning track, or another sighting gives a precise location.
From the 5 different maps, we can clearly see the celestial navigational capabilities of the ancients. Do keep in mind that navigational methods that are non-celestial (tidal, etc) were not taken into account. Although we have come to this common conclusion, we strongly believe that should the ancients really had needed to circumnavigate the globe, they would surely have been able to do that in time. More methods would have been developed for them to sail in places they have not ventured. In short, they are all winners.

CONCLUSION

We hope that you have enjoyed this issue of Starfarer. In addition to the brief historical introduction to the different cultures under scrutiny, we have also explored the various celestial navigational methodology of the ancients. To show you how they had managed to set sail with such confidence and success is not our sole purpose. Rather, it is our intent to set the reader thinking. To question the fundamentals of their techniques, the very basis of their rationale.

We acknowledge that the conclusions drawn are highly subjective. However, in the spirit of exploration, we have come up with our own hypothesis and hope that even if they are not entirely accurate, it will, at the very least, get the reader thinking about the validity of our claims.

Again, we reiterate the important fact that celestial navigation in early human history was never an exact science, and this tool was almost always used in conjunction with knowledge of other factors.

In all, we have enjoyed the process of making this issue of Starfarer. Through it, we have learnt numerous methods of celestial navigation used by the ancients. It is truly an enjoyable and enlightening experience, and we hope that it is through this manifest that you have acquired a similar sentiment.
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GEK 1506
HEAVENLY MATHEMATICS: CULTURAL ASTRONOMY
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