
NAVIGATION NOTES

VIKING NAVIGATION USING THE SUNSTONE, POLARIZED LIGHT AND THE HORIZON BOARD

by Leif K. Karlsen

How did the Vikings manage to navigate across the open ocean for thousands of miles without conventional instruments? Many books have been written about their amazing voyages, but they don't offer much detail to explain their navigational methods. Furthermore, there are practically no navigational relics from Viking era sites to reveal any secrets; most suspected navigation tools found so far have deteriorated beyond recognition.

To fill in this missing part of Viking lore, we must try to imagine ourselves in that time—driven to explore what lies beyond the sunset, possessing great common sense and courage, but lacking any tools and techniques of modern navigators.

Based upon my experience as a modern navigator and on hints given in the sagas and in the old Icelandic lawbook, the *Grágás* (Grey Goose), I firmly believe that the sunstone and some sort of a bearing board, similar to the horizon board described later, were used by the Viking navigators to guide them across the North Atlantic, and to other destinations they reached. These simple but effective aids to navigation allowed the Vikings to claim their place as one of history's great seagoing people.

The Vikings mostly sailed in the summer, when the northern latitudes are experiencing long days and short nights. Consequently, the Vikings depended on the sun rather than stars for navigation. At the latitudes where the Vikings sailed, no place in the region experienced true darkness in the summer. At latitude 61° North for example, from the end of April to the end of August the sun was available for more than 14 hours a day. At higher latitudes the sun was visible even longer. What more appropriate scheme could they have discovered to direct their ships, than to use sunlight refracted through a crystal found on the ground in Iceland? This crystal is called Iceland spar.

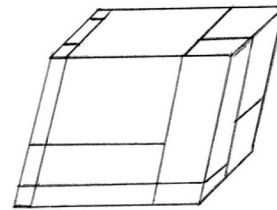
There were times during certain conditions, such as fog, that the sunstone could have been used at sunrise and sunset by the navigator. When very cold air moves over warmer water, wisps of visible water vapor may rise from the surface as the water "steams." In extreme cases this frost smoke, or Arctic sea smoke, may rise from a few feet to a height of several hundred feet. The portion near the surface forms a dense fog which obscures the horizon and surface objects, but usually leaves the sky relatively clear. Often in this type of fog, a ship passing by would have only the top of the mast showing with the surface fog obscuring the rest of the ship.

When the light from the rising or setting sun was lost in the fog bank, but the zenith was cloudless, the navigator could tell the exact position of the sun by using the sunstone, although the sun itself was unseen. Even on clear days, the horizon at sea is often obscured by haze or distant clouds. This is an ideal situation for using the sunstone to find the sun.

The basic principle of the sunstone (Iceland spar) is polarization of light, first described in 1669 by Erasmus Bartholimus, a Danish professor of mathematics and medicine, and a naturalist. Later on in 1678 the Dutchman Christiaan Huygens is his "*Treatise on Light*" writes that he also studied the double refraction Bartholimus had described in Iceland spar.

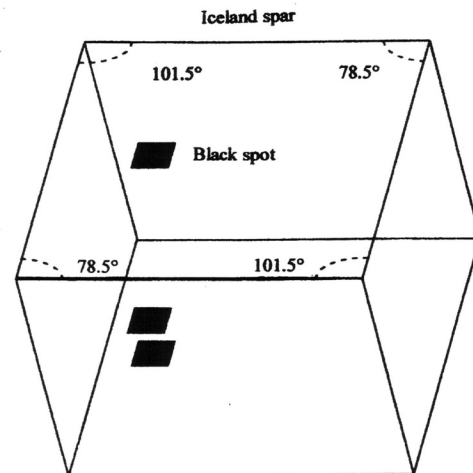
Iceland spar is also known as optical calcite and calkspat. In Iceland it is called *Silfurberg*. It is composed of molecules of calcium carbonate (CaCO_3), with the calcium atoms arranged in planes in a crystal lattice. Such crystal shows a natural cleavage. The crystal can be split into smaller crystals, all the way down to tiny pieces, always with the same angles as the original crystal.

Figure 1.



The crystal has a rhombohedral crystal structure, its opposite faces are parallel but there are no right angles. A perfect crystal is colorless and transparent. The angles are $101^\circ 30'$ for the obtuse angle and $78^\circ 30'$ for the acute angle. The structure of the crystal leads to the optical phenomenon of double refraction. An object viewed through the crystal will be seen as a double image.

Figure 2.



Sólarsteinn (Sunstone)

Direct sunlight is unpolarized, but the reflected sunlight that we observe in the blue sky is partly polarized. When sunlight passes through the earth's atmosphere it is scattered in all directions. The scattering is strongest for blue, the frequency in the visible range nearest to ultraviolet, thus giving the sky its characteristic blue appearance. At *sunrise and sunset*, the light reaching the observer has traveled farther through the atmosphere and those frequencies in the blue range have been removed by previous scattering. This allows the yellow and reds to predominate near the horizon in the twilight sky.

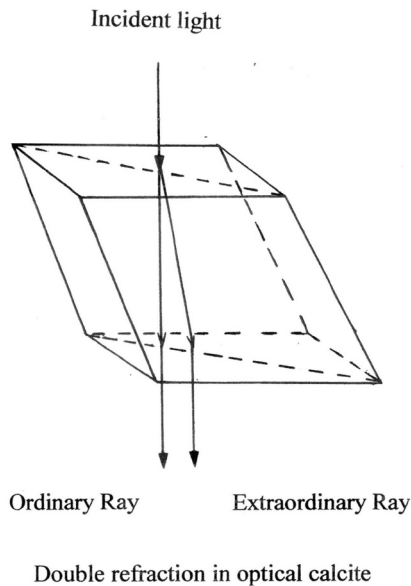
The scattering of sunlight by the atmosphere produces polarized light for a navigator looking at right angles to the direction of the sun, for instance, if he looks straight up at sunrise and sunset. If he is looking towards the sun, he sees unpolarized light that contains more red than blue.

The earth's atmosphere serves as a polarizer. If the sunstone is placed horizontal when the sun is on or near the horizon, it serves as an analyzer. The sunstone provides a directional reference during twilight, or when the sun is near the horizon in a fog bank, or behind an island, provided only that the zenith is cloudless.

A Demonstration using Iceland spar.

Iceland spar is well known material for its double refraction. When unpolarized light enters a calcite crystal it is split into two linearly polarized beams which are refracted by a different amount. The ordinary ray obeys the law of refraction; the extra ordinary does not, it bends away from the ordinary as it enters the crystal. The ordinary and the extra ordinary rays follow different paths inside the crystal, but when leaving the crystal they follow parallel paths.

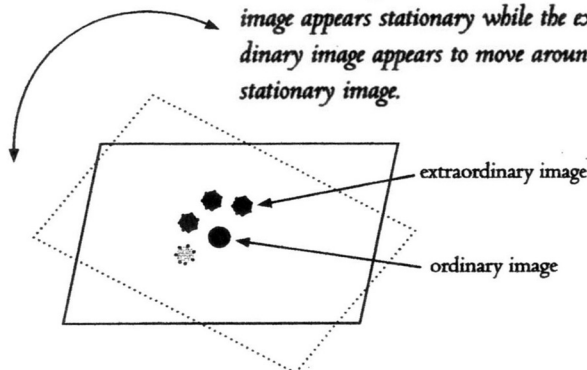
Figure 3.



Make a small mark on a piece of paper and place the crystal over it. You will see two distinct marks; both of them sharp and clear. Slowly rotate the crystal. One image will remain stationary as the crystal is rotated, this ray is called the ordinary ray. However, the other image will rotate with the crystal, making a small circle around the ordinary image. This is called the extra ordinary ray.

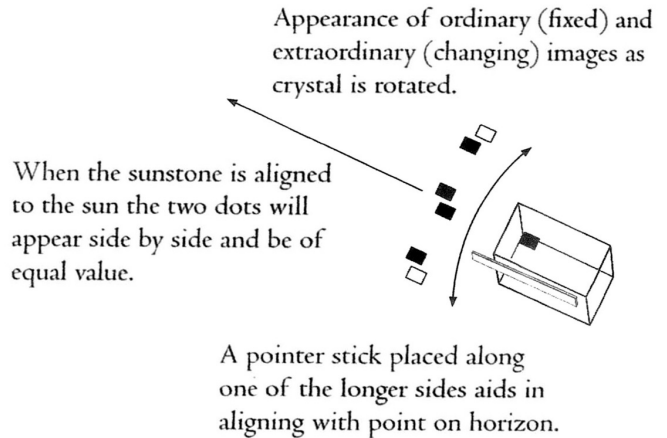
Figure 4.

As a calcite crystal is rotated, the ordinary image appears stationary while the extraordinary image appears to move around the stationary image.



In order to use a crystal as a sunstone for finding the sun, a small black dot is placed at the center of the top surface, so it will face up when the stone is held overhead. View this dot from underneath by looking up through the stone while holding it level to the horizon. You will notice the single dot appearing as two dots when viewed through the stone.

Figure 5.



Align a pointer to one of the long sides of the crystal, and point it towards the brightest area of the sky. Upon rotating the stone back and forth in the horizontal plane, you will see that one image fades and the other becomes darker. When the two images appear to be equal in value, note the position of the stone and pointer. The pointer is now aligned to the true bearing of the sun. It is accurate to within one degree.

For accuracy, the sunstone must be level and have an **unobstructed view of the zenith**, for if light does not enter the sunstone perpendicularly, an error is introduced. A thick cloud layer overhead scatters the polarized light from zenith, preventing the use of the sunstone.

Any Iceland spar crystal will work as a sunstone as long as it is optically clear. The thickness of the crystal is important. The thicker the crystal, the better is the refraction (separation) of the black dots.

Bearing at sunset

April 25th, 2006

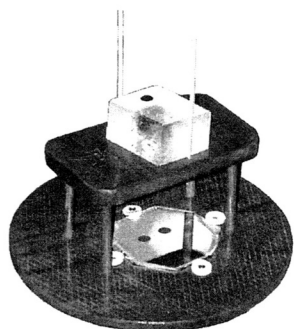
Location: Port Orchard, WA USA

Position: 48° 34.5' North, 122° 34.0' West

A bearing was taken at my home at 20:04:28 local time, (GMT 03:04:28) April 26th.

The bearing was taken shortly before sunset. The location of the sun was not visible, the sun was setting behind the forest. The zenith was cloudless. I had made a pedestal with a cutout hole for the sunstone, which sat on a mirror placed on a rotating wooden disk. It also contained two sighting pins on top. Instead of holding the stone up in the air and bending my neck backwards to look through from underneath, I could just glance into the mirror to adjust the stone.

Figure 6.



The author's sunstone stand showing the black dot on top of the stone and the reflected double dots in the mirror underneath. The advantage of this stand is that the observer does not need to hold the sunstone overhead and look up at the sky.

First I lined up the stone toward the relative brightness of the evening sky. Then it was rotated slowly back and forth until the double image was equal in value. I noted the exact time. I left the stand in a stationary position. Then a bearing was taken of the position of the stone, using the two sighting pins on top of the stand. This bearing was taken with a magnetic compass (Silva). After the bearings were taken, I used the Nautical Almanac for the year 2006, and the sight reduction table Pub. No. 249, volume 3 to calculate the true bearing of the sun. The bearing of the sun was 289°.

The bearing of the stone with the magnetic compass was 271° + 18°15' variation east, =289°15' true. The sunstone pointed to the hidden sun at 289° true.

I compared the sunstone bearing with the magnetic compass bearing **only** to show the accuracy of the sunstone.

The sunstone and the Horizon Board

The Vikings did not have a magnetic compass, but they had other ways to get their bearings and to guide their ships across the ocean. They divided the visible horizon into eight sections, which they called *attir*, meaning "main directions." They based this on the orientation of the Norwegian west coast, which runs approximately north and south.

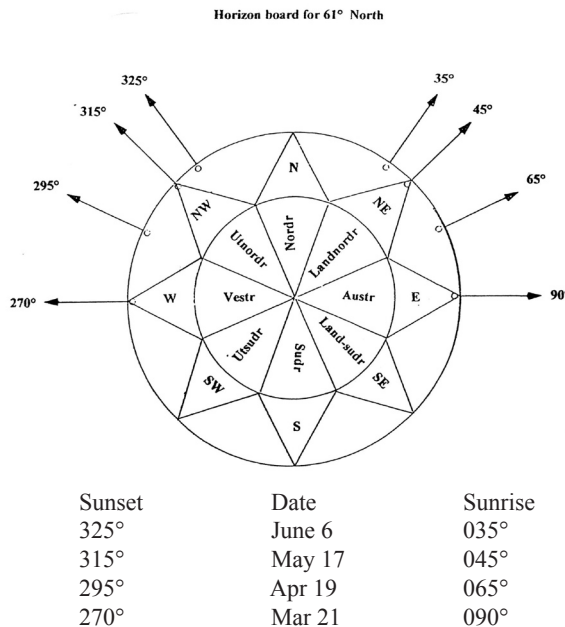
To demonstrate how the Vikings used the horizon board to get their bearings, I have created my own horizon board. This is not a replica of an artifact, but an original device based upon information from the Old Icelandic lawbook Grágás (Grey Goose), a title of uncertain origins.

The horizon board is simply a flat surface, such as a flat board, upon which is recorded the *attir*. Also indicated are the azimuths of sunrise and sunset over the sailing season on a certain latitude. The horizon board shows how this information about the sun and the eight sections of the horizon could be put to use in navigation.

The Vikings referred to latitude not by degrees but by the name of landmarks and places located at the appropriate latitude. For example: Instead of saying latitude 62° north, they used the name Stad, Norway, the place they sailed from, and the name of their destination, Thorshavn, Faeroe. The horizon board shows how the Viking navigator could, with observations he made at home, sail a latitude course from a homeport, across the ocean to his family's homestead, as recorded in the sagas.

The horizon board visually demonstrates the direction of the rising and setting sun during the months of May, June, and July at a given latitude. Small holes on the edge of the horizon board are used with wooden pegs to mark the direction to the sun.

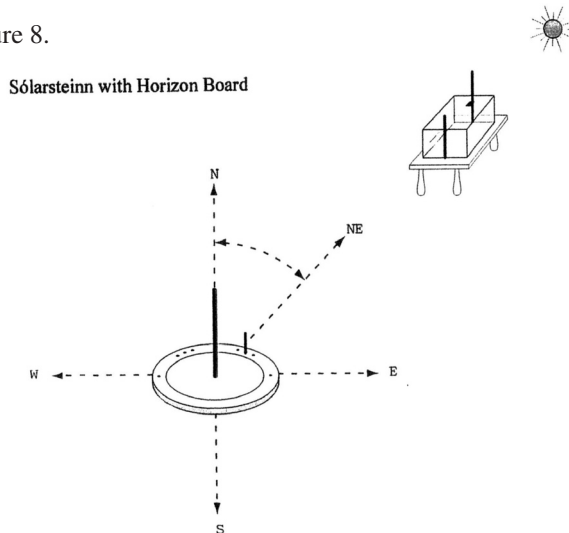
Figure 7.



The horizon board is quite easy to use. For example: assume the navigator desires to set a course due west from his departure point at Hernar Norway (61° North) on May 17st on a clear morning. The sun will rise here at 045°, Northeast. The wooden pegs on the horizon board will be set in the appropriate holes on the horizon board, and the true bearing of the sun will be taken. With an accurate reference bearing, the desired course west can be read from the horizon board. The same procedure is used for all other months. But if clouds or fog hides the sun, as is often the case in these waters, then the sunstone will be needed.

At sunrise on a morning with an obscured horizon and a clear zenith, the sunstone can be set up to find the exact bearing of the sun. When this is done, the horizon board will be aligned with the sunstone's bearing to the sun at 045°. The horizon board shows the sun's true bearing and the desired course can be determined from it.

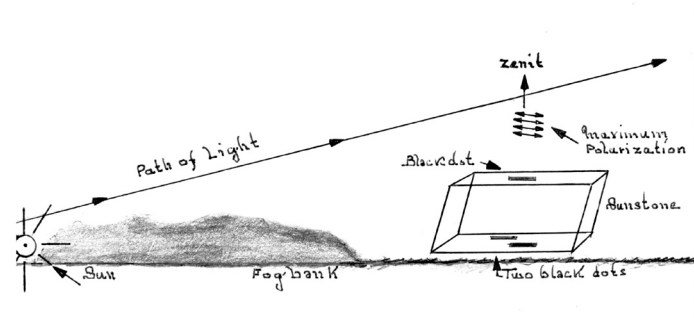
Figure 8.



A horizon board for other latitudes is easily made. The principle is the same except that the bearings are different.

During frequent foggy conditions, the use of the sunstone with the horizon board was a good combination, as the information obtained is truly valuable to the navigator. Knowing the location of the sun, he can align the horizon board and determine other directions hence the heading of the ship. Use of the horizon board also allows the navigator to make good use of the sunstone to find his course amidst a dense fog or clouds on the horizon.

Figure 9.



The sunstone pointing towards the relative brightness of the evening sky. At sunrise and sunset, the sun's rays are horizontal and the light from the zenith should be completely polarized.

References:

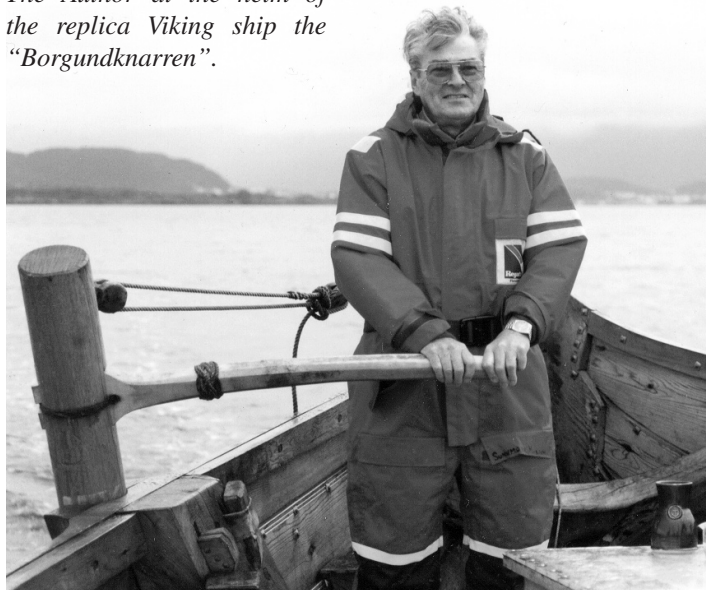
Bunn, W. Charles, *Crystals, Their Role in Nature and Science*, New York, Academic Press, 1964.

Huygens, Christiaan, *Treatise on Light*, University of Chicago Press, 1937.

_____, *H.O. Publication 216*, United States Government Printing Office, Washington, DC, 1955.

Pedersen, Einar Sverre, *Polar Navigation*, Scandinavian Airline System, 1956.

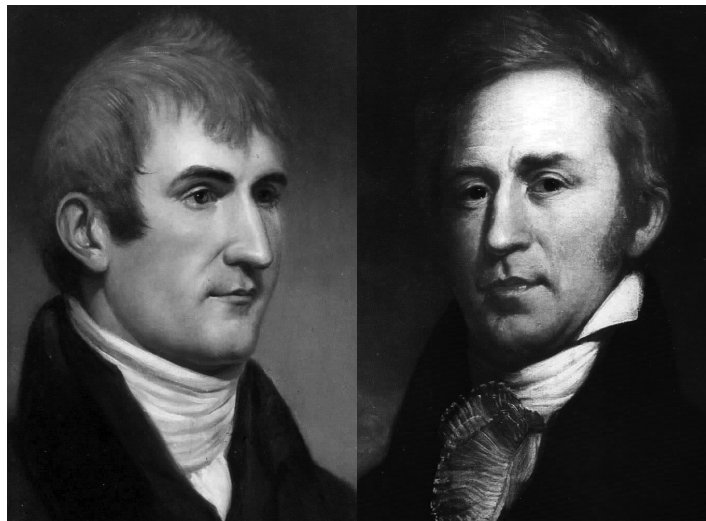
The Author at the helm of the replica Viking ship the "Borgundknarren".



NAVIGATION NOTES

LEWIS AND CLARK'S NAVIGATION, AN OVERVIEW

by Bruce Stark



Meriwether Lewis
1774 - 1809

William Clark
1770 - 1838

Part 1

Lewis and Clark found their way across the continent and back by following rivers and the advice of Indians. Strictly speaking, they weren't navigating, they were surveying. But that distinction doesn't concern us here. Our interest is navigation, and the Captains were using the techniques of navigation, altered to fit their needs.

Background

At that time the whole of the United States lay east of the Mississippi River. What little was known of the expanse beyond came from the writings and maps of French, Spanish, and British explorers and fur traders. French inhabitants of the lower Missouri had extended the trade up that river all the way to the Mandan Villages, in what is now North Dakota. David Thompson, working for a British fur company, had come to the Villages from the north, and had taken observations for latitude and longitude. The Mandan and Hidatsa informed the French and British that the river's headwaters lay in mountains far to the west.

A British survey of the Pacific coast, under Vancouver, had established the latitude and longitude of the Columbia River and mapped its lower reaches one hundred miles or so to the east.

Jefferson had reason to hope that the headwaters of the Columbia—or perhaps some other western river—lay near those of the Missouri, in the mountains of the continent's interior. If canoes could get to the headwaters of the two rivers, and furs and trade goods portaged between them, the United States would benefit both economically and strategically.