The Mystery of Extraordinarily Accurate Medieval Maps

Beautifully detailed portolan charts present historians with a puzzle: How were they made? A mathematical analysis offers some clues.

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Credit: Johann Baptist Homann after G.M. Lowitz, 1746

One of the most remarkable and mysterious technical advances in the history of the world is written on the hide of a 13th-century calf. Inked into the vellum is a chart of the Mediterranean so accurate that ships today could navigate with it. Most earlier maps that included the region were not intended for navigation and were so imprecise that they are virtually unrecognizable to the modern eye.

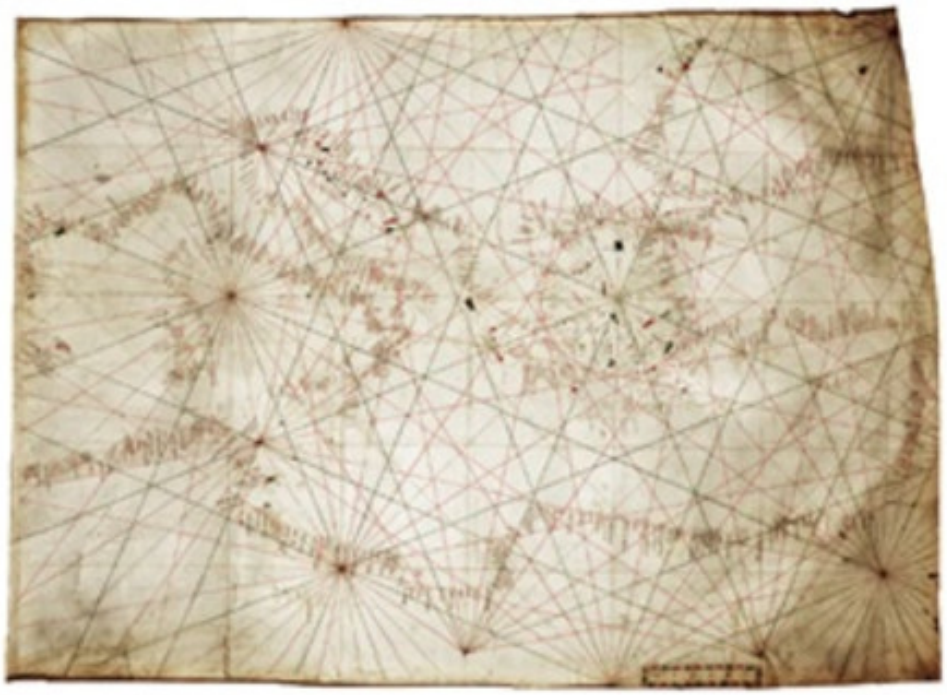
With this map, it's as if some medieval mapmaker flew to the heavens and sketched what he saw — though in reality, he could never have traveled higher than a church tower.

The person who made this document — the first so-called portolan chart, from the Italian word *portolano*, meaning "a collection of sailing directions" — spawned a new era of mapmaking and oceanic exploration. For the first time, Europeans could accurately visualize

their continent in a way that enabled them to improvise new navigational routes instead of simply going from point to point.

That first portolan mapmaker also created an enormous puzzle for historians to come, because he left behind few hints of his method: no rough drafts, no sketches, no descriptions of his work. “Even with all the information he had — every sailor’s notebook, every description in every journal — I wouldn’t know how to make the map he made,” says John Hessler, a specialist in modern cartography at the Library of Congress.

But Hessler has approached the question using a tool that is foreign to most historians: mathematics. By systematically analyzing the discrepancies between the portolan charts and modern ones, Hessler has begun to trace the mapmaker’s tracks within the maps themselves.



The oldest portolan chart in the Library of Congress collection, drawn between 1290 and 1350, depicts the Mediterranean Sea and the western Black Sea. (Credit: Library of Congress Geography and Map Division)

From Butterflies to Maps

Hessler’s path to mathematical cartography began with butterflies. A frustrated chemical engineer and a passionate amateur lepidopterist, he decided in 2000 to take a one-year contract job in the French Alps, studying the evolutionary relationships among the many butterfly species endemic to the region. He learned to use mapping software to track different butterflies’ geographic locations and deployed a technique called morphometrics to assess the relationships between the precise placement of the spots on their wings.

In his analyses, Hessler began by conceptualizing each wing as if it were drawn on a thin metal plate. In a computer simulation, he twisted and bent the plate to move the spots on the wing so they matched those on the wing of a butterfly in another region. He then calculated how much energy it would take to distort the metal into the new shape. The less energy required, the more similar the positions of the spots — and, perhaps, the more closely related the butterflies.

When his adventure in the Alps ended, Hessler's newfound mapping expertise landed him a job as a curator at the Library of Congress, where one of his duties was to maintain the vault that holds the institution's most rare and important maps.

There, for the first time, he saw a portolan chart, a coffee table-size map of the Mediterranean Sea. The rendering, created in 1559, was so accurate that it almost looked modern. The sole of Italy's boot had its improbable, graceful arch. He could make out each cove around Tunis. Tarifa and Tangier reached toward one another, like teeth, at the Strait of Gibraltar. It was a far cry from earlier Ptolemaic maps (see "Mapping the World," below), in which Italy's boot was painfully twisted and the teeth at the Strait of Gibraltar were stretched into flat hammer faces.

The portolan chart's inland portions were decidedly less modern, but they showed no shortage of imagination, featuring pictures of Italian dukes and, in Africa, unicorns and elephants illustrating "travelers' tales." But Hessler paid little attention to the fanciful characters. "The minute I saw one of the portolans, I was interested in its structure," Hessler says. "It's so different from the mathematical structure you see in [modern] maps."

The basic mathematical problem every mapmaker confronts is that the Earth is spherical and maps are flat. Imagine flattening a portion of a paper globe: You'll either have to tear the paper or crinkle it up to squish it down. Many modern maps solve this problem by using so-called Mercator projections, which turn the lines of latitude parallel to the equator and the lines of longitude that converge at the Earth's poles into a tidy grid of perpendicular lines on a flat plane.

What Hessler saw on the portolan chart was a different solution: a seemingly random pattern of lines showing the 16 directions (north, northeast, east-northeast and so on), spreading out from various locations. It seemed as though this helter-skelter mess of lines served as a kind of skeleton for the map — its "mathematical structure" — just like the tidy grid does for modern maps.

Fresh from his work using morphometric analyses to compare Alpine butterfly species, Hessler realized that a similar approach might allow him to compare a portolan chart with modern maps — and maybe even shed some light on the mystery of how they were made. Perhaps, he thought, he would find uniform distortions that would give a hint about how the portolan mapmakers approached their art.

Mysterious Method

To begin, Hessler studied the charts' history. Before the first portolan charts were drawn in the 13th century, Mediterranean sailors had no reliable drawings to guide them; instead, they relied on compass measurements combined with experience and lore to navigate the sea. Their sailing

records consisted of nothing more than lists of ports in the order that ships would encounter them, along with annotations including estimated directions, sailing times between ports and perhaps some sketches of geographic contours visible from afar, such as headlands projecting into the sea.

Hessler pictured the first portolan mapmaker at work, methodically working out some way to improve ships' odds of making it safely from port to port. He suspected the mapmaker began with one sailor's notes and sketches from a single voyage, starting at a single port — say, Naples. Then, perhaps, he drew a line to the next port, using the recorded sailing direction and time as his guide. He would have traced the journey to the next port, and then the next, making a circuit of the Mediterranean until his pen brought him back to Naples.

But the mapmaker would have run into a problem: The vagaries of wind, sea and imperfect records inevitably threw off the measurements, so that upon completing his vicarious journey, the mapmaker wouldn't land exactly on his starting spot. So he would have had to nudge his ports around to spread out the error. If he did the same thing again using a different set of sailing records, he would end up with ports in slightly different locations, and he would need to tweak the results again. No two of his charts would be exactly the same, and none would be quite right. The mystery is how he managed to reconcile all this contradictory, incomplete information into one brilliantly precise chart of the Mediterranean that allowed mariners to visualize, for the first time, the sea on which they'd spent their lives sailing.

(Credit: John Wolter/A Portolan Atlas of the Mediterranean Sea and Western European Waters/Library of Congress)

What Are the Key Features of a Portolan Chart?

This chart comes from a portolan atlas of the Mediterranean Sea and western European waters. Dating from about 1550, it is rare, since few such atlases from this period have survived. It has been attributed to Joan Oliva, the most prolific member of a large family of Catalan chart-makers. The chart exemplifies many key characteristics of portolan charts.

RHUMB LINES

These lines run out in 16 directions from points on the chart. It is unknown why these particular points were chosen and why certain points are illustrated with a compass rose whereas others are not.

DISTORTIONS

Portolan mapmakers lavished care on the Mediterranean because of the volume of maritime commerce there. Around Britain, the inaccuracies are greater.

DETAILS OF COASTLINE

The coastline is drawn with incredible accuracy, including the precise shapes of coves that a sailing ship couldn’t enter.

PORT NAMES

The name of each port is written alongside it, giving the coastline a soft appearance at a glance. Every aspect of the chart is drawn by hand.

To examine the underlying structure of this 1475 portolan chart, Hessler took a grid on a modern map and transferred it point by point to the chart. This method revealed a fairly consistent rotation of 8.5 degrees, which corresponds to the declination (the difference between magnetic and true north) at the time the chart was drawn. (Credit: John Hessler/Library of Congress Geography and Map Division)

Clues in the Errors

Hessler began to look for clues within the portolan charts themselves. Borrowing the morphometric techniques he used to track movement of the Alpine butterflies' spots, he transferred each point from a modern Mercator map of the Mediterranean onto the equivalent point on the oldest portolan chart at the Library of Congress. According to carbon dating of its calfskin substrate, this document was created sometime between 1290 and 1350.

The resulting grid on the portolan chart was slightly distorted in various small ways — not surprising, given the imprecise sailing data with which the mapmaker likely had to work. But it was also fairly consistently rotated by 8.5 degrees counterclockwise. Why?

Hessler suspected the skew was an artifact of compasses, which had arrived in Europe from China not long before the map was created. He knew that compasses respond to the Earth's magnetic field, which is generated by molten iron moving in the Earth's outer core. But magnetic north doesn't line up perfectly with true north, the point where the Earth's axis hits the surface

(and above which the North Star sits). The difference between magnetic and true north, called magnetic declination, varies slightly with time and place, reflecting shifts in the flow of the molten iron. Modern mapmakers correct for declination by adding or subtracting the appropriate number of degrees for particular locations.

Working from compass measurements but not correcting for declination could cause just the kind of rotation Hessler's analysis revealed. So he went on the hunt for information about historic declination and found a book that provided mathematical models estimating how the declination has changed over time. He consulted the estimates for around 1300, and *bingo*: 8.5 degrees. Now Hessler had strong evidence that the mapmaker, relying on sailors' records, didn't correct his measurements for declination. After all, Mediterranean mariners had no need to worry about how their charts were oriented with respect to the globe — they just needed a reliable guide for the region.

Hessler's detective work turned up one other clue to the mapmaker's method: Although the rotation was close to 8.5 degrees throughout the chart, it varied a bit. Italy was rotated only 6 degrees, while the Black Sea was rotated up to 8.8 degrees. That suggested the mapmaker created the chart using different observations made at different times. The result "highlights one of the most interesting problems that historical cartographers faced," says Hessler. How did the mapmaker decide which records to draw on? "Faced with all this data from different places and times, how did they know what was more accurate?" he adds.

Hessler analyzed other portolan charts in the same way, and each time, the correspondence with his book's predictions was nearly exact. Between 1300 and 1350, the declination in the Mediterranean fell by 2 degrees — and in keeping with that change, portolan charts drawn by the end of that period were about 2 degrees less rotated. By 1500, declination was back at 8.5 degrees, and so were most of the charts Hessler examined. Over the next 150 years, the declination shifted again, to 11 degrees, and the rotation of the charts followed suit.

To track how portolan charts' accuracy changed over time, Hessler drew again on the methods he used to quantify butterflies' evolutionary relationships. As with the butterflies' wings, he imagined each chart drawn on a metal plate and simulated bending it to move the landmarks on the medieval chart to meet their locations on a modern map. The less energy required to distort the metal into the new shape, the more accurate the chart.

Curiously, he found, in the first several decades after the first portolan chart was drawn, subsequent charts' accuracy declined a bit. Hessler speculates that the first portolan mapmaker's technique spread quickly, but those who adopted his methods initially lacked his skill, so their efforts were less precise. As mapmakers' skills steadily improved over the next two and a half centuries, so did the accuracy of their maps.

Across the Atlantic

As he pieced together answers to some of the questions that had vexed historians, Hessler says, "So many things amazed me: how much mapmakers of early portolan charts knew, how they

updated their data so quickly, how accurate their compasses were, how geographic information flowed around the world in ways that we don't understand."

Portolan charts paved the way for the age of exploration. Now, sailors could travel down the coast of Africa and around the cape. Eventually, maps were made that extended across the Atlantic to the New World. But paradoxically, the age of exploration that followed the creation of the portolan charts eventually led to their downfall, as increasingly sophisticated techniques of shipbuilding and mapmaking made them obsolete.

This depiction of the world as Ptolemy knew it, published in a 1482 edition of Geographia, was printed from carved wood blocks. Any maps Ptolemy himself created have been lost, but later scholars created maps based on his information. (Credit: Hain Collection , Library of Congress Geography and Map Division)

The problem was the portolan mapmakers' lack of a systematic way of reducing the spherical Earth to a flat map. That was of little consequence for short journeys but mattered much more when sailing longer distances. In 1569, the Belgian geographer and cartographer Gerardus Mercator created his method for presenting a spherical world on a flat map, the one familiar to us today. This mapmaking technique, though it stretched and compressed landmarks and distances between them, had the great advantage that a straight compass course was represented by a straight line on the map.

Mercator's projections began to be used to sail the open seas by the early 1800s, by which time portolan charts had pretty much disappeared. But their importance is undeniable. "The development of these maps revolutionized how people perceived space, much like Google Earth has done in our lifetimes," Hessler says. "Understanding how the technology was developed gives us insight into how we got here, and perhaps into where we're going."

This 16th-century portolan chart of the Mediterranean is vastly more accurate than any Ptolemaic map. Designed for marine navigation, the chart includes labeled seaports, giving the coastline a fuzzy appearance. (Credit: Library of Congress Geography and Map Division)

Mapping the World

The second-century Greek mathematician, astronomer and geographer Claudius Ptolemy founded the Western science of cartography.

From his study in Alexandria, Ptolemy assigned coordinates of latitude and longitude to 8,000 geographic locations, compiling the information into his *Geographia,* an atlas of world geography that included colored maps depicting regions of the then-known world.

This 1797 chart uses a Mercator projection. Devised by Gerardus Mercator in 1569, these projections, with their perpendicular lines of latitude and longitude, dominated nautical cartography by the 1800s. (Credit: Library of Congress Geography and Map Division)

Although Ptolemy's data were inaccurate, his work (translated into Latin in the early 1400s) influenced cartographers and explorers more than a millennium after *Geographia*'s publication.

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