Longitude

Columbus, along with Amerigo Vespucci, was at the absolute frontier of technology in his attempts to get an accurate measure of longitude. As reported by Alexander von Humboldt:

> [The] desire [of Vespucci and Columbus] to substitute the observation of the conjunction of the planets and the moon for lunar eclipses, and of thus increasing the ways of determining the longitude of a ship, was due to the influence exercised in Spain and Italy of Arab astronomy. From the century of Albategni to the work of Ibn Jounis, a long sequence of occultations of stars and oppositions of planets had been observed over a vast extent of countries, from Cairo to Baghdad and Racca. The change of direction which navigation was undergoing towards the end of the fifteenth century, made the necessity felt of obtaining and increasing the number of astronomical methods. But although it was possible to conceive of using [these new methods], the imperfection of nautical instruments hindered their success even more than the imperfection of tables. We have already seen, according to the journal of the first voyage of Columbus, the major part of which has been preserved for us by Las Casas, that the Admiral "sought, on the 13th of January 1493, in Haiti a port where he could tranquilly observe (*para ver en que paraba*) the conjunction of the sun and the moon, and the opposition of the moon and Jupiter."[11]

The science—in the broadest sense of the word—behind Columbus' achievement, was organized before he was born, at the Council of Florence. That does not diminish his glory, however. On the contrary, he was a fitting prototype of that once proud, now vanishing American, who has the ingenuity and imagination required to assimilate and put into practice the breakthroughs made by scientists—thus changing world history for the good, more than thousands of his detractors have changed it for the worse.

NOTES

1. Samuel Eliot Morison, *Admiral of the Ocean Sea: A Life of Christopher Columbus* (Boston: Little, Brown and Company, 1942), p. 195.
2. Alexander von Humboldt, *Examen critique de l'histoire de la geographie du Nouveau continent et des progres de l'astronomie nautique aux quinzieme et seizieme siecles* (*Critical Examination of the History of the Geography of the New Continent and of Navigational Astronomy during the Fifteenth and Sixteenth Centuries*), Vol. III, pp. 29-31 (translated from the French by the author).
3. In *Cosmos,* Vol. II, p. 262, Alexander von Humboldt speaks of a map of Toscanelli's, different from the well-known one, which Columbus had in his possession. For on Sept. 25, 1492, Columbus showed Martin Alonso Pinzon a map "on which many prominent islands were delineated."
4. Humboldt, *op. cit.,* Vol. III, pp. 29-31.
5. *Ibid.,* pp. 39-40.
6. E.G.R. Taylor, in *The Havenfinding Art* (New York: American Elsevier, 1971), pp. 162-63, says that the *Regimento* was probably written in 1481 by three people: master Rodrigo, the Royal physician to King John of Portugal; the Royal chaplain, Bishop Ortiz; and José Vizinho, a learned Jew and disciple of the famous astronomer Abraham Zacuto of Salamanca (who himself came to Lisbon approximately ten years later).
7. *Ibid.,* p. 164.
8. *Ibid.,* p. 164.
9. We do not use the great circle distance, because the practice at the time was latitude sailing, i.e., sailing down to the latitude you wanted (where the winds blew steadily in the desired direction), and then sailing along the latitude line.
10. This value also correlates very closely to the calculation we can make without the *Regimento,* based on the difference in longitude between the Cape Verde Islands and the Second Demarcation Line being about 22.5°; whence, 22.5° = 370 leagues, and 1° = 17.3 leagues.
11. Humboldt, *op. cit.,* Vol. IV, pp. 311-315.

SYMPOSIUM

Prince Henry's Navigations

by Tim Rush

Columbus' voyage across the Atlantic in 1492 was the westward application of the Apollo Project of the Renaissance: the coordinated advances in navigation, shipbuilding, astronomy, and mapmaking, pioneered by Prince Henry of Portugal ("the Navigator") (1394-1460).

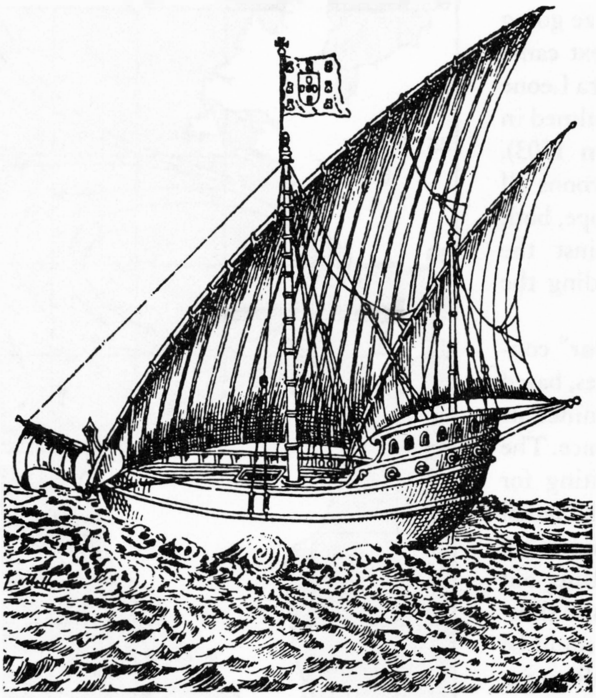
Henry's project was, in the words of the 1454 Papal edict which raised his efforts to a strategic priority for all Christendom after the 1453 fall of Constantinople, "to prove devotion to God by making the seas navigable."

From the period of Roger Bacon (c.1214-1292) and Ramon Lull (1232-1315), a strategic plan for Christianity to outflank the Venetian-Moslem grip on the eastern Mediterranean, by circumnavigating Africa, or heading west across the Atlantic, was on the table. This plan was further developed by the scientific participants of the

Council of Florence.

The logistical and technological problems were staggering. The boats of the time, both galleys and one-masted trading vessels, could not handle long voyages on the high seas; navigation and nautical astronomy was not developed for routes outside northern temperate-zone Mediterranean-centered requirements; there was almost zero knowledge of the complex winds and currents in the high seas; there was no first-hand knowledge of even the first five hundred miles of Africa coast, let alone the remaining eight thousand miles; and a vast body of medieval superstition had many sailors terrified that penetrating beyond the then-known limits of sailing was a suicide mission.

FIGURE 1. *The caravel, developed for ocean travel, maximized the efficiency of crew size, hull, and rigging, to gain speed and maneuverability.*



The School of Sagres

The third son of an illustrious generation of Portuguese princes, Henry sponsored a series of yearly voyages of discovery starting in 1416, when he was just twenty-two years old. By the early 1430's, he had established a scientific research center on the coastal promontory at Sagres, which came to be known as the "School of Sagres."

Sagres became the intersection point for all facets of Henry's project: his intelligence-gathering machine; the training of the personnel for the voyages within his household; the revolutionary advances in ship design centering on the caravel, carried out at the Lagos shipyards built and supervised by Henry; the design and execution of a colonization policy; all intermixed with a core group of resident cartographers, scientists, and geographers, and a stream of visitors from throughout the known world.

The center of his team, the only cartographer in the group known by name, was the Majorcan Jew Jahuda (Jacomé) Cresques. He brought a number of companions, and all the papers of his great father, the Abraham Cresques known as *magister mappamundorum et buxolorum* (master of the world-map and compass). Abraham Cresques had taught at Majorca's renowned school of navigation; he had designed the famed Catalan Atlas of 1375, among many other cartographic achievements; he had mastered the manufacture of navigational instruments; and he had perfected a series of tables to calculate sea distances.

The Invention Of the Caravel

The development and introduction of the caravel under Henry's sponsorship in the period around 1440, was one of the great technological leaps of the Renaissance.

Galleys were out of the question for deep-sea ocean travel—the ratio of numbers of seamen required to ship size meant impossibly large requirements of food and water. The barca and varinel, used by Henry in his early voyages, were round-bellied, heavy merchant ships, difficult to maneuver and riding low in the water. They used just one mast and one large sail.

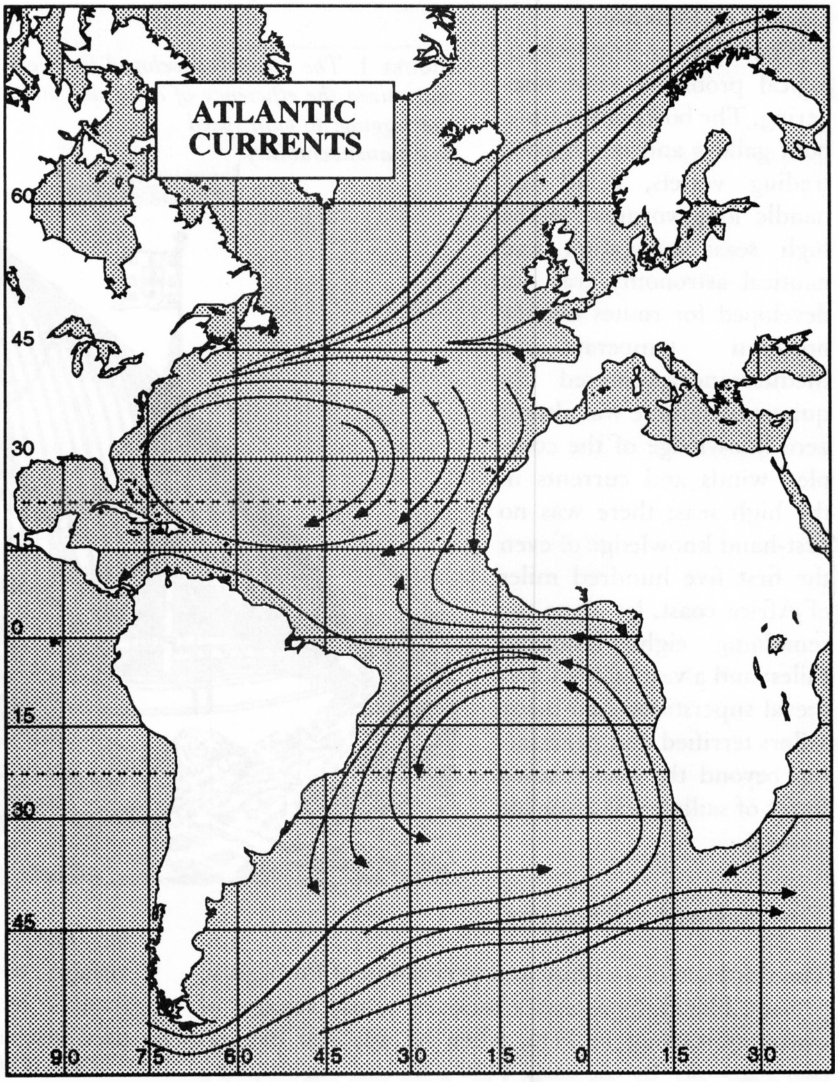
Out of Henry's shipyards came an "intrinsically revolutionary vessel, with respect to both rigging and hull design. She was three-masted and usually lateen rigged." The ratio of beam to length was not 1:2, but 1:3, and even 1:4. "It was thus the combination of hull, size, and rig that made the caravel far and away the most efficient sailing vessel built up to that time. Excellent in windward work, these ships could sail anywhere but into the 'eye of the wind,' while their daily runs in favorable weather sometimes rivaled the logs of the famous clipper ships of a later day."[1] The caravel later became the standard ship of Columbus' voyages (SEE Figure 1).

The 'Long Ocean Tack'

The caravel opened one of the great deep-sea achievements of Henry's, or any later, time: what became known as the "Guinea tack," or sometimes, the "long ocean tack."

Examine closely the pattern of winds and currents that the Portuguese had to contend with as they proceded further and further down the Africa coast (SEE Map VI). Down to approximately the 15th parallel, at the "bulge" of Senegal, both wind and water currents tend uniformly south and southwest. It was literally a breeze going out—but hell tacking back. Next came the problem of calms off the Sierra Leone coast (an Italian crew stayed becalmed in the area for fifty-seven days in 1503). Further south, from the Cameroons all the way to the Cape of Good Hope, both winds and currents run against the south-bound mariner, while aiding the return.

The result was that any "linear" conception of the exploration voyages, based on paralleling the coasts, undermined its own viability the longer the distance. The time taken in tacking and waiting for favorable winds, coupled with the lethal results of tropical heat and diseases on the crews; of tropical waters rotting out the wooden hulls; and slimmer and slimmer margins of provisions that could be carried for such long distances, all meant that no sustained course of exploration, evangelization, or commerce, could be carried out on that basis.

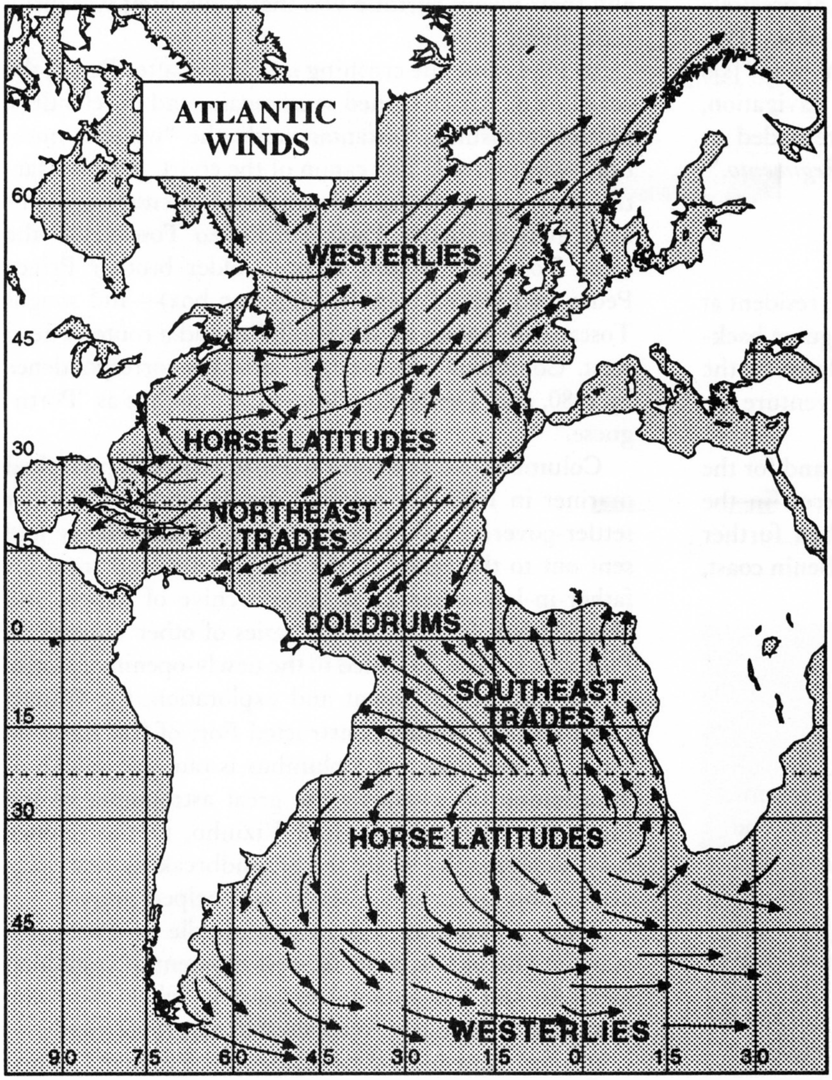


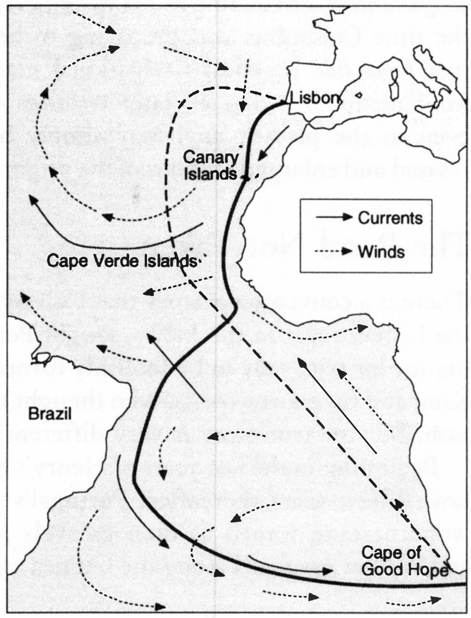
MAP VI. *Opposite vortex patterns of currents and winds in the North and South Atlantic.*

Henry's crews hit upon a unique and extraordinary solution to the problem. As the voyages probed further and further south, the captains began to set sail at an oblique angle to the contrary winds they faced heading home. They headed north and northwest. But instead of tacking a few miles, and then tacking back in the opposite direction, they kept going—for up to a thousand miles of open ocean, until they reached the vicinity of the Azores. They they turned east, utilizing the variable winds of that latitude which shuttled them relatively securely due east to Lisbon. The two legs of this "long ocean tack" involved distances substantially greater than the direct route— but an equally substantial saving in time (SEE Map VII).

This solution was then inverted and extended into the southern hemisphere for the great breakthrough of Vasco da Gama's voyage to India in 1497. What Da Gama did—after a decade of intense Portuguese researches into the wind and ocean currents of the South Atlantic—was sail with the prevailing winds and currents to the latitude of the Cape Verde Islands (again, utilizing the generally clockwise circulation of wind and ocean in the northern hemisphere); then, cut across the doldrums to intersect the mirroring counterclockwise circulation in the southern hemisphere, and follow it *southeastward,* almost to the coast of South America. (Alvaro Cabral, in the next voyage, would officially "discover" Brazil by exactly this "longer ocean tack"—a discovery almost certainly made earlier by the crews doing the reconnoitering for the breakthrough!) Once in the "roaring 40's" of the southern Horse Latitudes, Da Gama "hitchhiked" a ride back on the eastward winds, to intersect the Africa coast at almost precisely the Cape of Good Hope.

It was a route that was not to be improved upon in the next four hundred years, and although for Da Gama it involved being out of sight of land for over three





MAP VII. *The "long ocean tack." Solid line: Portugal to the Cape of Good Hope; dashed line: from the Cape to Portugal.*

months and 3,800 miles (compared to Columbus' thirty-three days and 2,000 miles), it cut the time of the passage in half. It was a staggering feat of seamanship.

Columbus' masterly use of the circulatory pattern of the northern belt for his voyage (out on the Trade Winds, back in a northerly route intersecting the Azores), shows his acute learning abilities in the Portuguese "long ocean tack" methods.

The *Regimento*

Coupled with the School of Sagres revolutions in shipbuilding and use of winds and currents, was a revolution in navigational astronomy. Mariners from time immemorial had used the Pole Star as a rough guide to their latitude. However, the needs for charts and tables were minimal, since voyages took place within a relatively narrow belt of latitudes and usually had visual landmarks within several days of sailing to correct any errors. The giant distances out of sight of land introduced by Henry's navigators forced the Portuguese to bring the extensive astronomical knowledge and sophisticated instruments of court astronomers within the reach of common sailors—heretofore considered too lowly a profession to merit access to them.

Thus, in the last years before Henry's death in 1460, we find the first consistent mention of the use of the quadrant on board the Portuguese caravels. Within twenty years, the design and use of the astrolabe had been adapted by the successor to Henry's School of Sagres, the "Junta dos Matemáticos" in the Lisbon court, to become an increasingly common instrument on board (Columbus carried both).

A problem of an entirely different order presented itself to the Portuguese when they neared and then crossed the Equator, in the years 1454-1474: the Pole Star rode lower and lower on the horizon, and then disappeared. There was no southern equivalent for the Pole Star. A navigational guide to determine latitude below the Equator was required.

Based upon centuries of accumulated knowledge of *solar declinations,* the result was the great joint work of two Jewish astronomers and mathematicians, Abraham Zacuto and José Vizinho, the *Regimento do Astrolabio e* *do Quadrante,* circulating in manuscript form at precisely the time Columbus was preparing to head west. This first *bona fide* practical navigational manual was "[s]o fundamental . . . that all later treatises on navigation, even to the present day, may simply be regarded as revised and enlarged editions of the original *Regimento.*"[2]

The Road Not Taken

There is a conventional story that Columbus, resident at the Lisbon court in the 1480's, sought Portuguese backing for his trip, only to be foolishly turned down by the King and his court experts, who thought the venture too rash. But the true story is very different.

Beginning in the last years of Henry's life, and for the next fifteen years thereafter, Portugal's interest in the western route waned as their caravels pushed further and further eastward along the Guinea and Benin coast, and their joyous surmise was that India itself was just a little ahead.

In 1474 came the crushing shock that after Benin, the coastline of Africa turned south again, and in relentless, unbroken fashion. Instantaneously the "western question" was revived. The canon of the court, Fernão Martins, exchanged correspondence with Florence's pre-eminent mathematician, Paolo dal Pozzo Toscanelli—the same Toscanelli whom Henry's older brother Prince Pedro had visited back in 1428 (SEE box)—and sought Toscanelli's advice on the feasibility and a route to head west. Columbus was brought into this correspondence by 1480, and Toscanelli addressed Columbus as "Portuguese."

Columbus had first come to Portugal as a shipwrecked mariner in 1476. He married the daughter of the first settler-governor of Madeira, whom Prince Henry had sent out to the island in the early 1420's, and from his father-in-law inherited a large archive of papers and observations. In 1482, after a series of other voyages on Portuguese ships, he sailed to the newly-opening frontier of Portuguese settlement and exploration, the Guinea Coast and the freshly-constructed Fort of São Jorge da Mina. A later letter of Columbus is our sole source of information on a trip by the great astronomer of the Junta dos Matemáticos, José Vizinho, to the Guinea coast to personally verify the groundbreaking new solar declination tables and rules he had helped prepare.

Thus, Columbus was in the middle of Portugal's maritime breakout, at its densest moment of combined scientific and navigational expansion, when the route west was as seriously considered as the route south.

It is fortunate indeed for history that a man of Columbus' determination and strength, energized by direct contact with the Florentine scientist Toscanelli, and backed by the greater resources of Spain, stepped forward to take the "road not taken" by the Portuguese, and thus ensured that Henry's project to "show devotion to God by making the seas navigable" brought the Renaissance Christian world simultaneously to the American continent and, by the Africa route, to the Indies.

Portugal and Florence

In 1425, Prince Henry's older brother Pedro embarked on a four-year mission, which was one of the widest and most successful diplomatic and scientific expeditions in the history of Europe. When he arrived in Florence, he became the toast of the city. A joust was held in his honor, and literary works were dedicated to him. "The humanists made much of the Portuguese prince."[3] Among the aims of his mission: "to look for geographic materials for Prince Henry his brother. . . . He certainly must have frequented, among others, Palla Strozzi, Antonio Corbinelli, who had had sent from Constantinople geographic codices, and especially Cosimo de' Medici and the nucleus of his gifted intimates, who met with him at the convent of the Angeli, [hosted by] Ambrogio Traversari; among whom the main ones were Lorenzo de' Medici, Ser Ugolino Pierúi . . . and finally Paolo dal Pozzo Toscanelli."[4]

The ties to the mathematician Toscanelli would define the most fruitful of multiple threads of political, economic, and scientific collaboration for the rest of the century. For, as one of Italy's most distinguished Columbus scholars put this widely-suppressed fact, "the Florentines played an active part in financing and stimulating the Portuguese maritime enterprises."[5]

NOTES

1. Boies Penrose, *Travel and Discovery in the Renaissance,* (Cambridge: Harvard University Press, 1952).
2. *Ibid.*
3. John Dos Passos, *The Portugal Story* (Garden City: Doubleday and Co., 1969).
4. Gustavo Uzielli, "Paolo Toscanelli, Amerigo Vespucci, and the Discovery of America," in *Paolo dal Pozzo Toscanelli, iniziatore della scoperta d'America. Ricordo del Solstizio d'estate del 1892* (Florence: 1892), as translated by Rick Sanders.
5. Paolo Emilio Taviani, *Christopher Columbus: The Grand Design* (London: Orbis, 1985).