A SYMPOSIUM | **The Discovery of the Americas and the Great Scientific Project of the Renaissance**

Columbus and Toscanelli

by Ricardo Olvera

One of the most controversial matters relating to the discovery of the Americas relates to the Italian Renaissance. In the scientific seminars held during the Council of Florence, Paolo dal Pozzo Toscanelli presented his idea of the project. Based upon the scientific information brought by cosmographers, geographers, and experts in the science of navigation gathered there together, the general lines were traced of what would, fifty-three years later, become the "greatest event after Creation," according to one Spanish author—the discovery of the New World.

The direct connection between the Italian Renaissance and the Spanish exploit is established by the correspondence between Paolo dal Pozzo Toscanelli and Christopher Columbus. In Toscanelli's letter to Columbus in 1480, and in the ones written by him six years before to Fernão Martins, agent of the Portuguese King Alfonso V, the Florentine scholar urged the Iberian powers—Portugal and Spain—to realize the transatlantic project discussed in Florence, and he laid out for them the map and the scientific information required for its success (SEE Map I).

As Fernando Columbus, Christopher's son, reports in his *Life of the Admiral,* the basis upon which his father founded his project was as follows:

> A Master Paolo, physician of Master Domenico, a Florentine contemporary to the same Admiral, was the cause in great measure of his undertaking this voyage with greater spirit. The fact that the cited Paolo was a friend of Fernão Martins, canon of Lisbon, and that the two were writing letters to each other about the sea voyages made to the country of Guinea during the time of King Alfonso of Portugal, and about what could be done in the westward direction, came to the ears of the Admiral who was most curious about these things. And he hastened to write, by way of one Lorenzo Girardi, a Florentine who was in Lisbon, to the said Master Paolo, about this, and sent to him an armillary sphere, revealing to him his intent. Master Paolo sent him a reply in Latin. . . .

Later Fernando Columbus transcribes the first letter from Toscanelli to Christopher Columbus:

> To Christopher Columbus, Paolo, physician, greetings.
>
> I see this magnificent and grand desire of yours to see how to get to [the regions] where spices are born, and in reply to your letter I send you a copy of another letter which I wrote some time ago to a friend and familiar of the most serene King of Portugal, before the Castillian war, in reply to another letter which by commision of his Highness was written to me about the said matter; and I send you another such map of sailing, as the one I wrote to him, through which your questions will be satisfied.

Toscanelli affixed to the bottom of his letter to Columbus, a copy of the letter which he had sent earlier to Fernão Martins, the canon who operated as an intermediary between the republican networks of Florence, and those republicans who were trying to convince the King of Portugal to put the navigational capacity of that country in the service of this great project. This letter had been directed at awakening the commercial interest of

This article, translated by Rick Sanders, has been excerpted and adapted from "The Discovery of the Americas and the Great Scientific Project of the Renaissance," which appeared in the Spanish-language magazine Benengeli, *Vol. 2, No. 1 (1987).*

the powerful, painting with vivid colors the fantastic riches of the Far East; and attached to it was the *carta de marear* or "navigational map," which Columbus never let out of his sight for even a moment, during his first voyage.

Did Toscanelli believe that following his navigational plan, the coasts that one would see rise on the horizon would be those of the Orient? Or did he perhaps expect those of a new continent? One fact makes us suspect the latter: the distance at which Columbus encountered America, and likewise the principal geographic and nautical characteristics of the route, were precisely those of Toscanelli's navigational map. Instead of fantastic palaces covered in gold and the refined civilization of the Orient, Columbus encountered an almost savage continent, in which everything still needed to be done. The prevailing mentality of the courts of Europe at the time, would have made it very difficult to find support for a project involving so much nature and so little art.

Either way, Toscanelli and the strategists of the Renaissance succeeded in their plan to mobilize the maritime-commercial powers to an enterprise which the "experts" of the age considered "not income-producing" (just as today, the cost-accountants consider the project of colonizing the Moon and Mars as not "income producing"), and such experts notwithstanding, there was opened up for humanity the most formidable period of development of which we have memory.

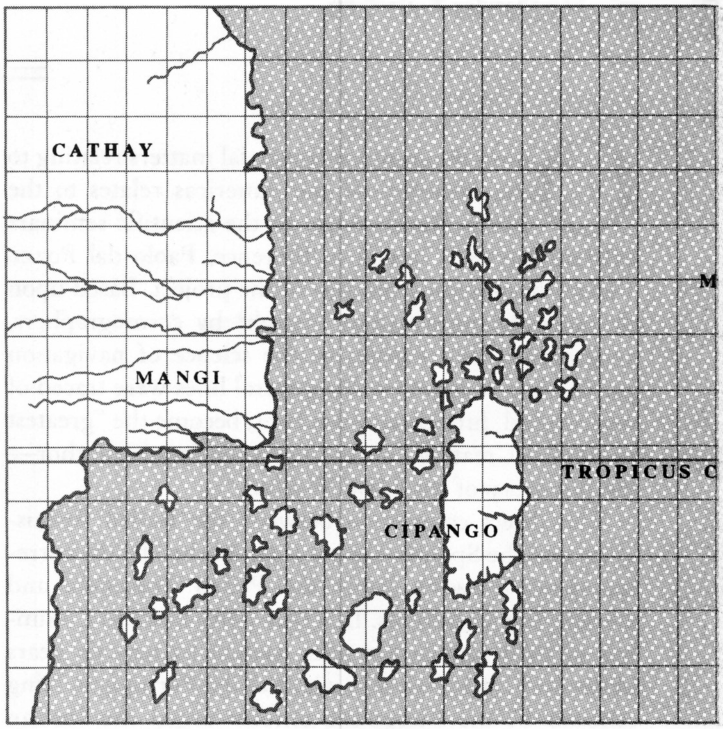
Are Toscanelli's Letters Genuine?

At the Congress of Americanists held in Paris in 1900, Henry Vignaud, then First Secretary of the American Embassy in France, denied for the first time the authenticity of the famous correspondence between Toscanelli, Martins, and Columbus, in a document which was immediately widely diffused through the press of the day. Over the years since 1900, the vital and previously well-known link of Columbus to Toscanelli—and thus, to the Council of Florence—was hidden, and ultimately, forgotten.

In essence, Vignaud said that the discovery of the Americas was not the result of any scientific project, but rather of chance. According to Vignaud, Columbus never had any intention of reaching Asia, let alone the New World, but only of reaching one of the islands located west of the Canaries. If by chance Columbus did have any scientific theory, he would not have gotten this from Toscanelli, nor from any of the cosmographers of the Renaissance, but from Ptolemy, Aristotle, and other "authorities" of medieval geography and cosmography.

Vignaud based this on his "demonstration" that the letters of Toscanelli to Christopher Columbus, and above all from Toscanelli to Fernão Martins, were apocryphal. In refuting this assertion, the historian Clement Markham argued that

> [f]ew documents of this period are so well certified [as this letter]. Las Casas, an absolutely trustworthy and honest historian, not only furnishes us with a Spanish translation, but informs us that one part of the original, it seems, the navigational map adjoined, was in fact in his possession at the moment of writing. In the *Life of the Admiral,* by Fernando Columbus,



MAP I. *Reconstruction of Toscanelli's map sent to Columbus in 1480.*

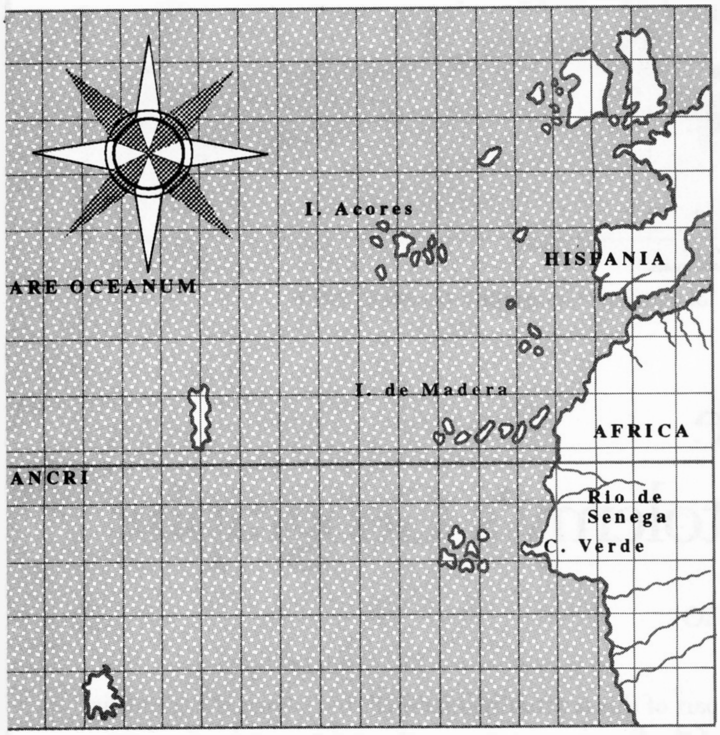
> there is included an Italian translation. And one copy of the original version in Latin was found in the Columbus Library in Seville in 1860, in the frontispiece of a book by Pius II which had belonged to Christopher Columbus, written in the Admiral's own hand.[1]

In a reply to Markham, Vignaud attempted to bolster his claim by arguing that Fernão Martins never existed, and that *he was a mere invention,* created to explain the inexplicable: the tie between Columbus and Toscanelli—which was impossible according to Vignaud, because Columbus was never in Florence, and Toscanelli never left Italy.

Did Fernão Martins Exist?

Ironically, by questioning the existence of Fernão Martins, Vignaud actually helps us to highlight the point of conception of the Renaissance exploration project.

For in the work of Cardinal Nicolaus of Cusa entitled *Tetralogus de Non Aliud* (*Tetralogue on the Not-Other*), there unfolds a Socratic dialogue between "Nicolaus" and three interlocutors, of whom the main one is *Ferdinando Martin Portugaliensi natione,* canon of Lisbon, whose full name is Fernão Martins de Roritz (from the



town of Roritz in Portugal). The other two are Oanes Andrea Vigerius, or Gian Andrea, from Vigevano in northern Italy; and Petrus Balbus Pisanus, or Pietro Balbi, born in Pisa, a former study companion of Cusa and Toscanelli in Padua. This same Fernão (Martins) of Roritz, relative and private councillor to Alfonso V, would, together with Toscanelli, later sign on Aug. 6, 1464, the last will and testament of Nicolaus of Cusa, as a witness and as his personal doctor; a few days later, he would attend Cusa's funeral.

A relative of Fernão Martins also enjoyed the confidence of Cardinal Cusa: Antonio Martins, the bishop of Oporto, born in Chavez, a town near Roritz. It is this Antonio Martins who had accompanied the cardinal's delegation to Constantinople in 1437, sent by Pope Eugene IV to convince the Emperor and the Patriarch of Constantinople of the need to be present at the Council.

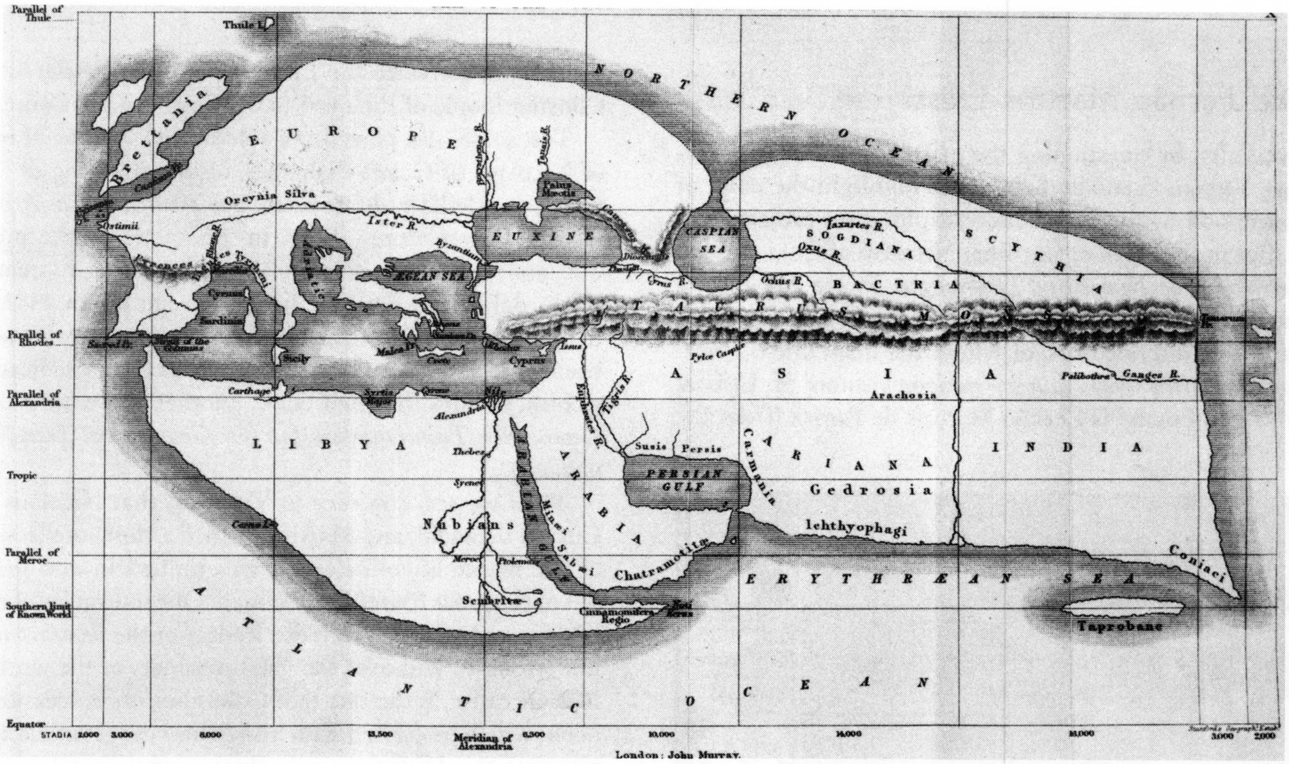
Toscanelli also played the role of interlocutor in one of Nicolaus of Cusa's dialogues, on the squaring of the circle, entitled *De Arithmeticis Complementis* (*On Arithmetical Complements*). Born in 1397, one of the most outstanding participants in the Council of Florence, Paolo dal Pozzo Toscanelli died at age 88, in 1482, a decade before the realization of his great project. He had been Cusa's fellow student in Padua, and Cusa dedicated to him, besides the cited book, another one entitled *De Geometricis Transmutationibus* (*On Geometrical Transformations*).

Thus we see, contrary to Vignaud, that Nicolaus of Cusa, Toscanelli, and Martins formed a close intellectual circle, whose scientific work was unified in and grew out of the great Florentine Council. One indication of the educational efforts which the leaders of the Renaissance undertook to win over the "best mariners of the world" to their cause, is the fact that Columbus' most treasured book, which he carried with him in his voyages of discovery, was the *Historia rerum ubique gestarum* (*Universal History of Facts and Deeds*) of Pope Pius II—the humanist Aeneas Silvius Piccolomini—in whose frontispiece Columbus himself had copied in his own hand Toscanelli's map. It had been Piccolomini who penned the great lament at the fall of Constantinople to the Turks in 1453: "This is a second death for Homer, a second death for Plato: now where will we be able to find the works of genius of the Greek poets and philosophers?"

Pope Pius II died on Aug. 14, 1464, three days after Cardinal Cusa, and the chances of an immediate Christian crusade to liberate Constantinople and free the Mediterranean from Turkish control, were sharply reduced; this thread would be picked up later, through the Reconquest of the Iberian peninsula, brought to a close in 1492 by the same Ferdinand and Isabella who would dispatch Columbus that same year on the greatest military flanking move in history—to bypass the Venetian-Turkish stranglehold, and reach the east by the rear, going west across the feared *ocean-sea.* And thus it was that, after the deaths of Cusa and Pius II, the scientist Toscanelli returned to Florence "to continue his studies, turning his face not to the east, but to the west, thinking about a new route for commerce and for civilization."[2]

NOTES

1. Clement R. Markham, *Toscanelli and Columbus: A Letter from Clement R. Markham to Henry Vignaud* (London: Sands and Company, 1903).
2. Angel de Altolaguirre y Duvale, *Cristobal Colon y Pablo del Pozzo Toscanelli* (Madrid: Imprenta de Administracion Militar, 1903).



MAP II. *The World of Eratosthenes, in E.H. Bunbury's* A History of Ancient Geography *(London, 1879).*

SYMPOSIUM

The Battle Against Ptolemy's Geography

by Salvador Lozano

When the sages gathered at the Council of Florence examined the viability of the project which came to life in the voyages of Christopher Columbus, they first had to settle various questions related to the form and composition of our planet which had been discussed for many decades.

For example, in the absence of precise geographic data, the distance to be navigated westward from Europe before finding land must be estimated from the size of the globe; the probable proportion between the surface area of land versus water; and so forth. On the other hand, to plan explorations, they had to resolve the double question: which part of the world is habitable, and which part of this is actually inhabited. In essence, the scientists of the Renaissance were making the same kinds of conjectures that we do today when discussing the conquest of the solar system.

The geographical knowledge of Mediterranean civilization had arrived at a high level just prior to the beginning of the Christian era. Outstanding for their contributions were Eratosthenes, the astronomer Hipparchus of Rhodes (second century B.C.), and the historian Strabo (first century B.C.). Maps II and III are the maps derived from the work of Eratosthenes and Strabo, respectively, and illustrate, among other things, the fact that they were well aware that Africa came to an end at a southern cape that was circumnavigable. It is probable that they knew of the Phoenician expedition sent about 609-593 B.C. by the Egyptian Pharoah Necho II to circumnavigate Africa by departing from the Arabian Sea, as reported in the famous account by Herodotus in *The Histories.*

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It is worth noting that Hipparchus subjected the work of Eratosthenes to stringent criticism, for his lack of rigorous method in dividing the map into zones and in situating places with precision, a method which must be based in the exact placement of parallels and meridian lines from astronomical observation. Hipparchus, who compiled a catalogue of no less than 1,980 stars, followed this method to correct the location of a good number of places, using for the first time in cartography the division of the Earth's circumference into 360°.

It must be kept in mind, however, that the various volumes of the *Geographika* of Strabo constitute more a formidable descriptive encyclopedia, than a conceptual work Hipparchus-style. In fact, regarding astronomical or mathematical material, Strabo frequently refers his readers to Hipparchus.

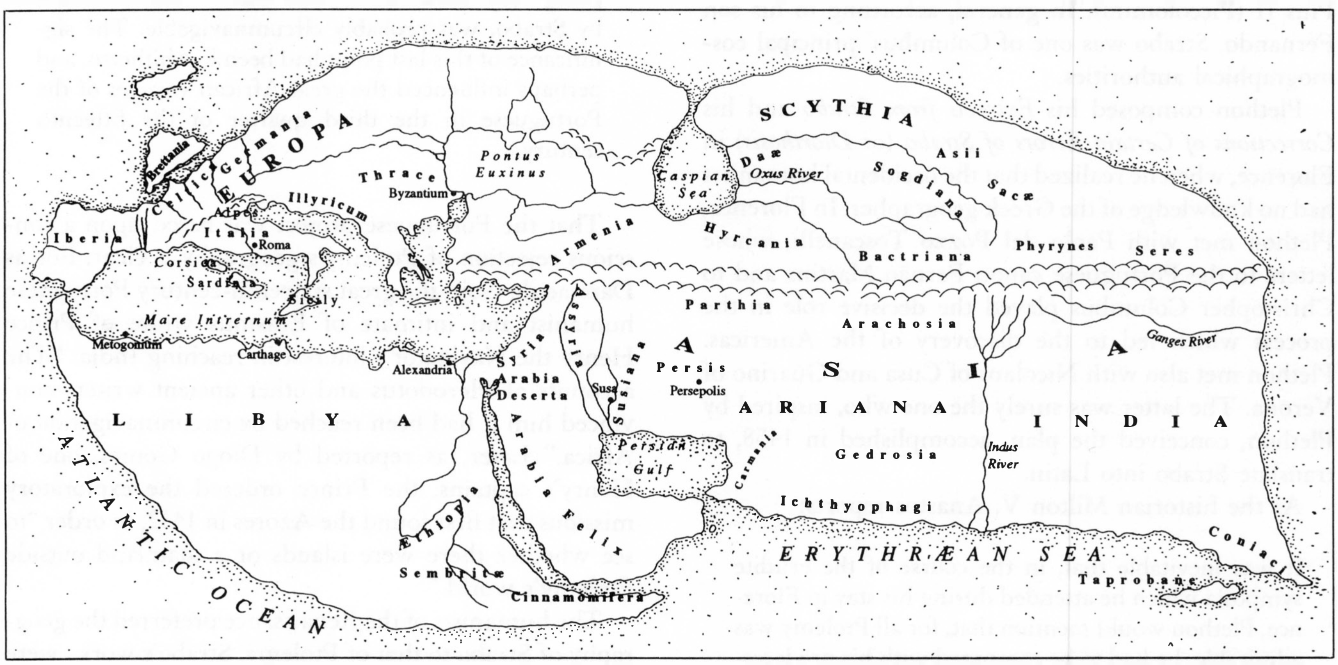
Some three hundred years after the death of Hipparchus, the fanatical Aristotelian Claudius Ptolemy (90-168 A.D.) became director of the library of the Alexandrian Museum. One of the biggest intellectual swindlers in history, who perpetrated frauds in astronomy, optics, and music, as well as geography, Ptolemy concocted a series of fables of which the most scandalous was that Africa is not circumnavigable because it is connected to an unknown land (*terra incognita*) which entirely surrounds the Indian Ocean (SEE Map IV). As for the distribution of land and water on the planet's surface, Ptolemy spread the discouraging idea that water covers upwards of five-sixths of the whole planet. Moreover, he placed rigorous limits on the habitable and the inhabited world.

The Council of Florence

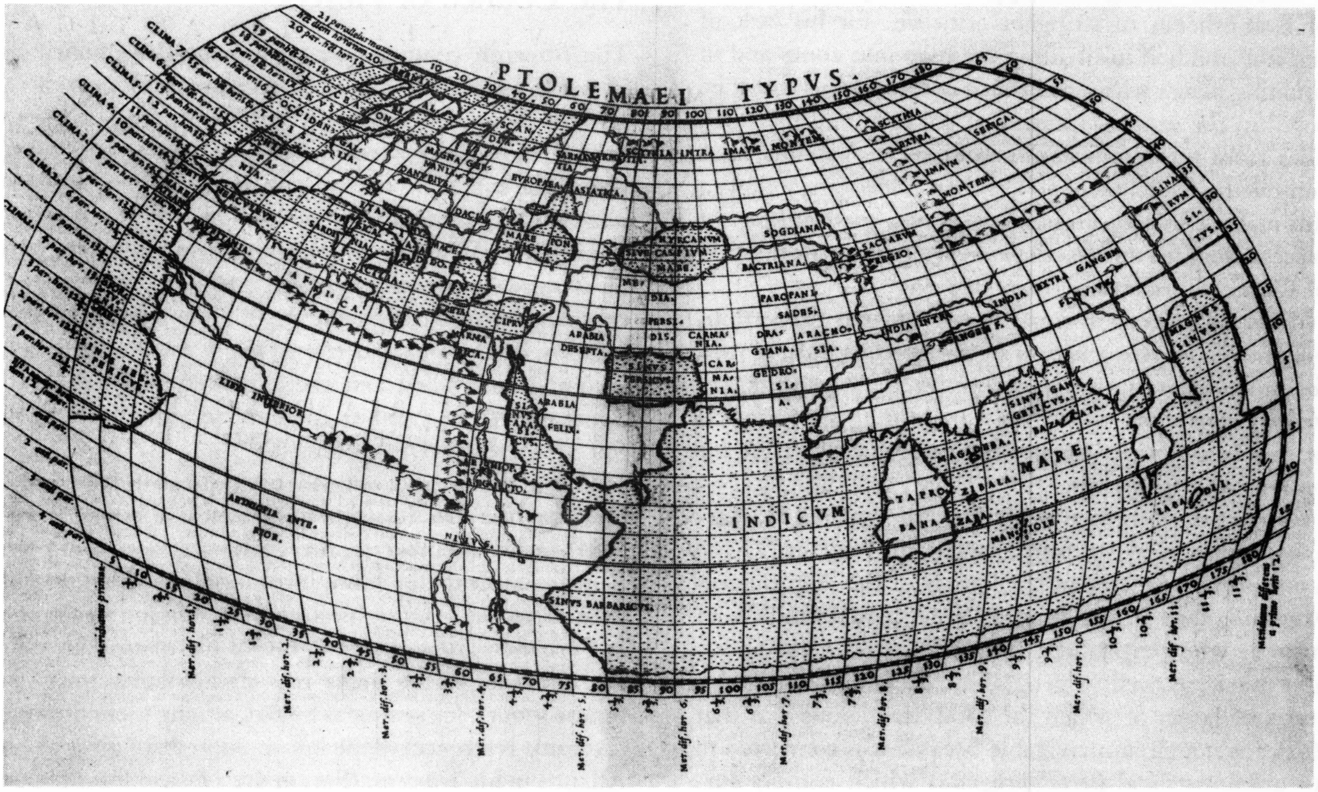
The fifteenth century, the century of the Council of Florence and the discovery of the Americas, provides a vista of bitter conflict: the efforts of the humanists to resolve the geographical questions posed by the great project of exploring the western route to the East, collided with the attempts to obscure all this through the charlatanry of Ptolemy and his promoters—especially as his treatise *Geographika Syntaxis,* which had been almost completely forgotten during the Middle Ages, had only recently been translated from Greek into Latin, a task accomplished, aided and abetted by strenuous promotional efforts, by Jacobus Angelus de Scarparia a mere thirty years before the Council.

One of the decisive events at the Council in this respect was that the erudite Greek, Gemistos Plethon (1389-1464), a lay member in the group accompanying the Paleologue Emperor John, introduced the Western humanists to the geographical encyclopedia of Strabo.

Fernando Columbus, the son of the discoverer, calls our attention to the many reasons his father found in Strabo's work for sailing as he did, among them Strabo's favorable references to the information Plato gives about Atlantis in his *Timaeus.* (For, in the *Timaeus,* based upon very ancient oral traditions, Plato speaks of "terra firma situated on the other side of this true ocean," which could be reached by sailing "from one island to another.") Columbus must have cited this and other observations directly from Strabo's text, since none of these quotes are given in other works by other authors whom Colum-



MAP III. *The World of Strabo. Reconstruction based on E.H. Bunbury's* A History of Ancient Geography *(London, 1879).*



Map IV. *The World of Ptolemy, in Girolamo Ruscelli's* La Geografia di Claudio Tolomeo *(Venice, 1561). Note the strip of land which connects Africa to Asia and encloses the Indian Ocean—making the circumnavigation of Africa impossible.*

Reprinted from sources in the George Peabody Library of the Johns Hopkins University

bus had studied or annotated. Columbus referred to Strabo to support the notion that there exist habitable regions as yet unknown; and he frequently referred to Strabo in his comments on the *Historia Rerum* of Pope Pius II (Piccolomini). In general, according to his son Fernando, Strabo was one of Columbus' principal cosmographical authorities.

Plethon composed his *Extracts from Strabo* and his *Corrections of Certain Errors of Strabo* (or *Diorthosis*) in Florence, when he realized that the occidental humanists had no knowledge of the Greek geographer. In Florence, Plethon met with Paolo dal Pozzo Toscanelli, whose letters to the Portuguese canon Fernão Martins and to Christopher Columbus played the decisive role in the process which led to the discovery of the Americas. Plethon met also with Nicolaus of Cusa and Guarino of Verona. The latter was surely the one who, inspired by Plethon, conceived the plan, accomplished in 1458, to translate Strabo into Latin.

As the historian Milton V. Anastos reports:

> It was inevitable that, in the course of the erudite symposia which he attended during his stay in Florence, Plethon would mention that, for all Ptolemy was admirable, he had to be compared with his predecessor, Strabo, whose *Geographika* corrected and augmented in many points the work of Ptolemy on the same subject. Among other things, he will have drawn people's attention to, as he does in the *Diorthosis,* Ptolemy's idea that the Indian ocean is landlocked being very questionable; and that Africa, as taught by Strabo, was probably circumnavigable. The significance of this last point had been lost hitherto, and perhaps influenced the great African voyages of the Portuguese in the third quarter of the fifteenth century.

That the Portuguese project was based upon a conscious rejection of Ptolemy's geography is clear. For as Damiao de Gois, the great sixteenth-century Portuguese humanist and intimate of Erasmus wrote of Prince Henry the Navigator's interest in reaching India: "The accounts of Herodotus and other ancient writers convinced him it had been reached by circumnavigation of Africa." Later, as reported by Diogo Gomes, one of Henry's captains, the Prince ordered the exploratory missions that first found the Azores in 1432, in order "to see whether there were islands or a mainland outside Ptolemy's world."

The humanists of the Renaissance preferred the geography of Strabo to that of Ptolemy. Strabo's works were printed various times between 1469 and 1473, before the work of Ptolemy was even printed for the first time, in 1475. Pope Pius II definitively rejected the Ptolemaic description of Africa and adopted that of Strabo—which was that of all the classical Greek geographers.

This illustrious Pope says, in his *Asiae Europaegue Elegantissima Descriptio:*

> Asia is joined to Africa by the nape of Arabia which separates our sea [the Mediterranean] from the Arabian Gulf. No one denies this; but he [Ptolemy] adds that at a certain point, they are connected by an unknown land mass which encloses the Indian Ocean. In this opinion he is almost alone. Because all the ones we know who wrote about the features of the Earth, place the Indian Ocean south and east, without ascribing to it any limit, hence they are of the opinion that it is a part of the *ocean-sea,* as recorded by those who navigated from the Arabian Gulf to the Atlantic Ocean and the Pillars of Hercules.[1]

For this reason, when Bartolomeo Diaz circumnavigated the Cape of Good Hope, Christopher Columbus judged the event, and rightly so, as the practical refutation of the Ptolemaic description of the limits of the inhabited world, and a powerful argument in favor of the project in which he played such an outstanding part.

NOTES

1. A clear reference to the expedition of Pharaoh Necho II.

SYMPOSIUM

The Science Behind Columbus

by Rick Sanders

For the modern reader, the attempt to discover the scientific and technological significance of Columbus' 1492 voyage is probably almost as difficult as it was for him to do what he did in the first place. Even leaving aside the politically motivated detractors of Columbus and his exploit, his admirers are not always helpful. Admiral Samuel Eliot Morison, for example, tries to have it both ways. First, he says that Columbus was barely capable of using the astrolabe and the quadrant, and that he underestimated the size of the Earth by twenty-five percent; later, he goes on to say that Columbus was among the world's best navigators, and that "no man alive, limited to the instruments and means at Columbus's disposal, could obtain anything near the accuracy of his results."[1]

To understand the outlines of how the science of Renaissance navigation positioned Columbus to undertake his great voyages, we have to answer the following questions:

- **What general cosmological and navigational knowledge, other than the astronomical sciences, was required to carry out the 1492 exploit?**

And, as to the astronomical sciences, we must know:

- **With what kind of accuracy could Columbus determine latitude? Did he use the stars, the sun, or both?**
- **How close was Columbus in his estimate of the Earth's circumference?**
- **If Columbus knew the Earth's circumference, did he know the size of the "hole" between Spain and "Cipango" (Japan); that is, did he know to what longitude Asia stretched, so that he might calculate the actual distance between East Asia and Spain?**
- **Did Columbus have any reliable way of finding longitude?**

Cosmology and General Seamanship

Cosmology

The "politically correct" cosmological view at the beginning of 1492—despite the counter-tradition of Nicolaus of Cusa and the Council of Florence—was that of Aristotle and Ptolemy, that the known world was an island in the midst of a chaotic, untraversable ocean. Columbus had the courage to accept instead the conclusions of Pierre d'Ailly, Cardinal of Cambrai, who in his 1410 *Imago Mundi* said:

> The length of the land toward the Orient is much greater than Ptolemy admits. . . .For, according to the philosophers and Pliny, the ocean which stretches between the extremity of further Spain [Morocco] and the eastern edge of India, is of no great width. *For it is evident that this sea is navigable in a very few days if the wind be fair.* [This part is heavily underscored by Columbus in his copy of the book.][2]

The Winds

Columbus assimilated the knowledge passed on to him by the Portuguese—including the portolan sailing charts and maps that he inherited from his father-in-law, Bartolomeo de Perestrello—and combined it with his own sailing experience and observations made while living in the Azores—for example, that between 25°N and 30°N, the wind blew steadily from the east, whereas at the Azores, the wind blew steadily from the west. Hence, without hesitation—clearly, he had mapped it all out in advance—Columbus sailed straight down to the Canaries, virtually due west at the right latitude; while on the way back, he sailed north as fast as he could to the latitude of the Azores, and then due east.[3]

The Magnetic Compass

Sailors, even well-versed in navigational astronomy, and with modern navigational aids, must still use *dead reckoning* to get an appproximate position. In first approximation, you assume the small surface you are covering to be flat, estimate your average speed, compensate for any currents, plot how far you have travelled north or south, and east or west, and complete the triangle. But on a cloudy day—or cloudy weeks, as is often the case in the North Atlantic—you must have a magnetic compass to determine the direction in which you are sailing.

The magnetic compass had arrived in Europe probably from China some time between 1000 and 1111 A.D.. Now, the magnetic field lines of the Earth are relatively constant (changing only over decades or centuries) for a specific latitude and longitude; and even though it is true that the magnetic compass did not point exactly to true astronomical North in Europe at the time of Columbus, this variation was constant and was routinely corrected for, using astronomical readings, by compass makers.

But, when you change longitude and latitude, your compass may begin to vary wildly. As Alexander von Humboldt recounts Columbus' experience:

> The important discovery of the magnetic variation, or rather, that of the change of variation, in the Atlantic Ocean, belongs, without any doubt, to Christopher Columbus. He found on his first voyage, on the 13th of September 1492, that the compasses, whose declination had been up till then to the northeast, declined towards the northwest, and that this declination to the west increased the following morning. On the 17th of September. . .the magnetic declination was already a quarter of a wind, "which very much frightened the pilots.". . .
>
> The observation of the 14th of September 1492 [marks] a memorable epoch in the annals of *navigational astronomy* of the Europeans. [All emphasis and quotation marks in the original.][4]

Humboldt makes clear that Columbus' discovery was not that of the *variation* of the magnetic compass, but that

> west of the Azores, the *variation* itself *varied,* that from N.E. it became N.W., and that on one occasion when none of the eight or ten pilots travelling with him had any idea where they were, Columbus used the declination of the compass to assure everyone that he knew where they were, one hundred leagues west of the Azores.[5]

Latitude

Any amateur astronomer can determine his latitude *on land* within a half a degree or so, with a simple homemade quadrant. It is enough to measure how far Polaris (the Pole Star) is above the horizon: that angle is your latitude. At the time of Columbus, Polaris was about 3½° off true North, so simple corrections based on the relative position of the two brightest stars of the Little Dipper, or the position of Cassiopeia, were required. A simple way to do this was written into the main handbooks, such as the oldest surviving navigation manual, the *Regimento do Astrolabio e do Quadrante.*[6]

The other primary way of determining latitude is to measure how far the sun is above the horizon at noon, take into account the declination of the sun above or below the celestial equator for that day. The information required to do this—primarily the tables of declination for the sun—were to be found in the same *Regimento,* in the section on the "Rule of the Sun," which gave the sun's position in the Zodiac, and its declination day by day. According to historian of navigation E.G.R. Taylor, "in the list of latitudes which the manual provides, the positions are with few exceptions, correct within half a degree—often to within ten minutes."[7]

But, could navigators determine their latitude from shipboard? Yes, but less accurately. There are places to stand on a ship where the pitch and roll are very small; then you could take various readings, compensate for motion, etc. Navigators must have been able to do this quite accurately, or else common "latitude sailing"—sailing along a latitude line—would have been impossible.

Columbus Knew the Earth's Circumference

A common piece of disinformation circulated to discredit the project that culminated in the discovery of the Americas, is that "Columbus underestimated the size of the Earth by twenty-five percent." This allegation is backed up by a dispute over the length of the "mile" and "league" in Columbus' day.

However, there is a direct and obvious way to prove the contrary—that Columbus knew the circumference of the Earth virtually exactly.

Columbus got his education in advanced navigation in Portugal. The oldest surviving navigation manual, the *Regimento do Astrolabio e do Quadrante* cited above, contains a statement that allows us to prove without serious doubt that the length of the league used at the time of Columbus was correct, and corresponded to the correct circumference of the Earth:

> Know that the degree of North-South is 17½ leagues, and that sixty minutes make a degree.[8]

Proof

We can prove the length of the league, using the Second Demarcation Line, which today's scholars show cutting Brazil at 46.5° West—just as it appeared on the Portuguese *Cantino World Map* of 1502 (SEE Map V). According to the 1494 Treaty of Tordesillas, this line was to be located "370 leagues west of the Cape Verde Islands."

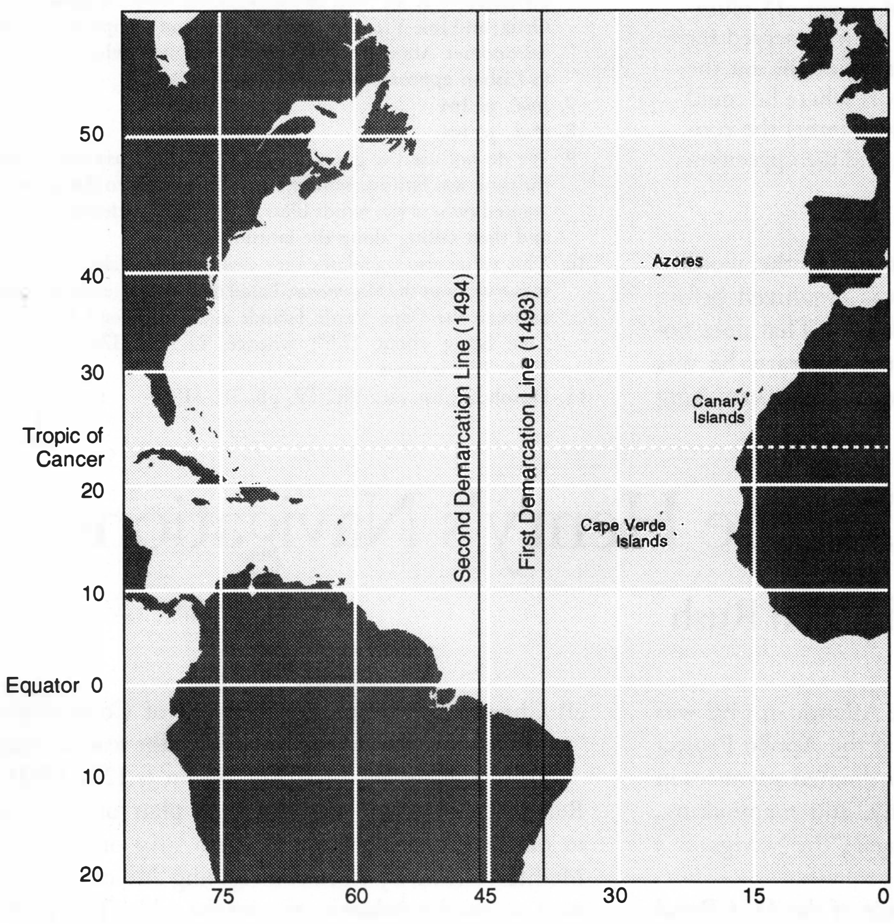
- Since the average longitude of the Cape Verde Islands is 24° West, the difference between the Islands and the Demarcation Line is $46.5° - 24° = 22.5°$;
- Therefore, the linear distance[9] between the Islands and the Demarcation Line is $22.5° \times 111.116$ km $\times$ cosine 16° (the average latitude of the Cape Verde Islands) = 2,403.26 km;
- Therefore, since 370 leagues was set at 2,403.26 km, 1 league = $2{,}403.26 \div 370 = 6.4953$ km.;
- And, since according to the *Regimento* there were 17.5 leagues to the degree,[10] the circumference of the Earth would come be to $17.5 \times 360 \times 6.4953 =$ 40,920.4 km.

The actual average value for the Earth's circumference is calculated today at 111.116 km $\times 360° = 40{,}001.8$ km!

Distance between Spain And 'Cipango' (Japan)

This is a more difficult question, since maps before Columbus do not show a continent between "Cipango" and Europe. It appears that Marco Polo did not know how to determine longitude (which became possible only in the late fifteenth century, when almanacs began to be published predicting eclipses and occultations of planets and stars by the moon). Marco Polo seems to have estimated the distance he travelled by the land equivalent of dead reckoning, something which is not easy, given mountain ranges, deserts, and so forth. Thus, even if the size of the Earth were known, it would be difficult to determine with any degree of exactitude, the size of the "hole" between the Canaries and "Cipango" (SEE Map I).

Out best guess is that the Florentines, basing themselves on Plato's account of Atlantis, or on Pliny, or on Pierre d'Ailly, might have concluded that there was land about thirty days sailing west. Perhaps they thought this was India; perhaps, something else.



MAP V. *The Second Demarcation Line, 1494.*

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).

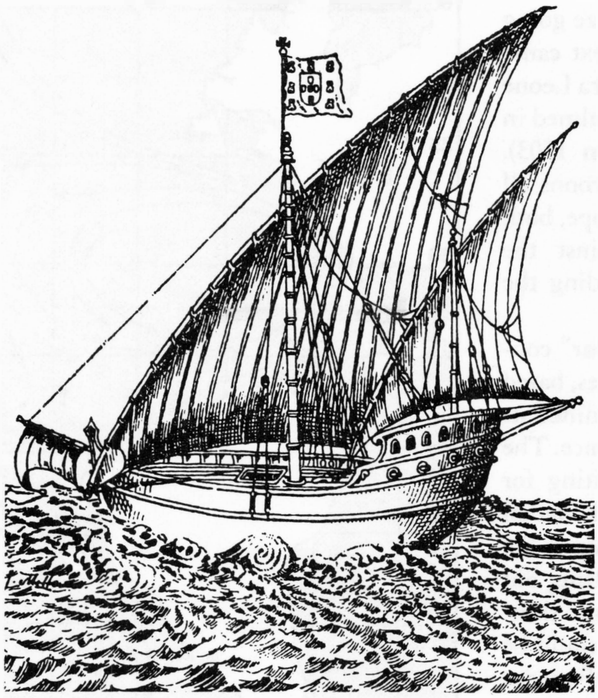
Henry's project was, in the words of the 1454 Papal edict which raised his efforts to a strategic priority for all Christendom after the 1453 fall of Constantinople, "to prove devotion to God by making the seas navigable."

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'

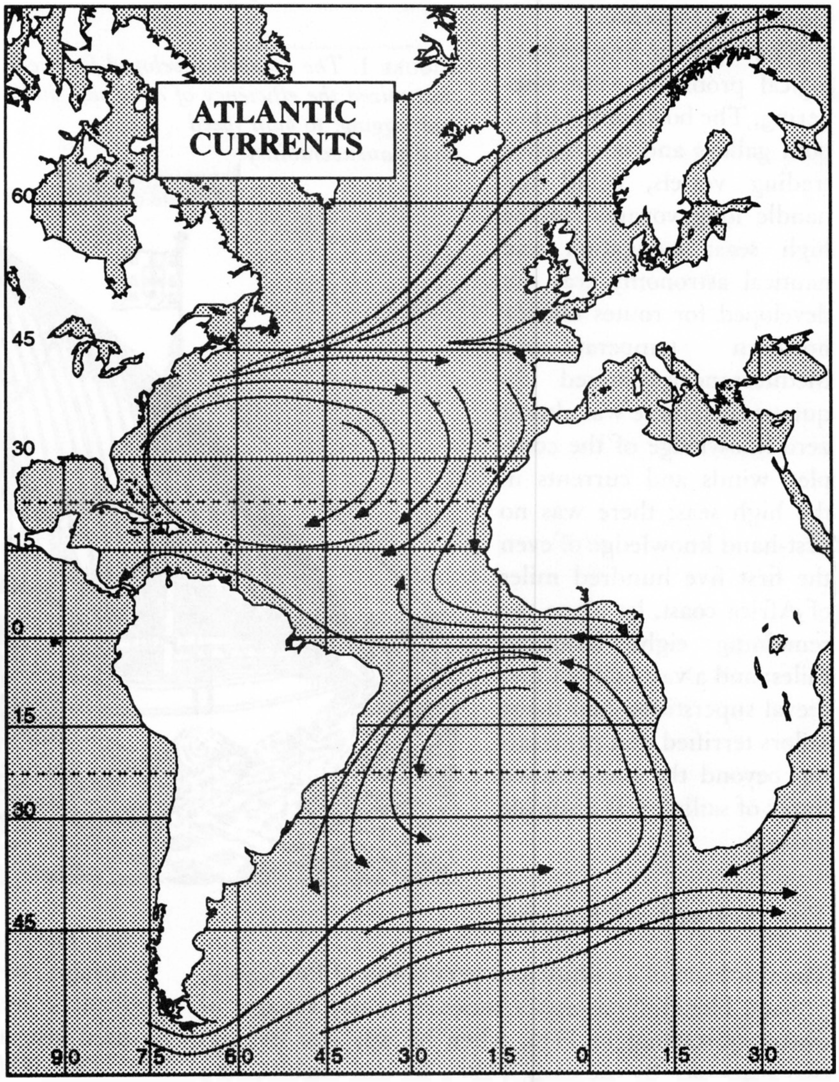
The caravel opened one of the great deep-sea achievements of Henry's, or any later, time: what became known as the "Guinea tack," or sometimes, the "long ocean tack."

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.

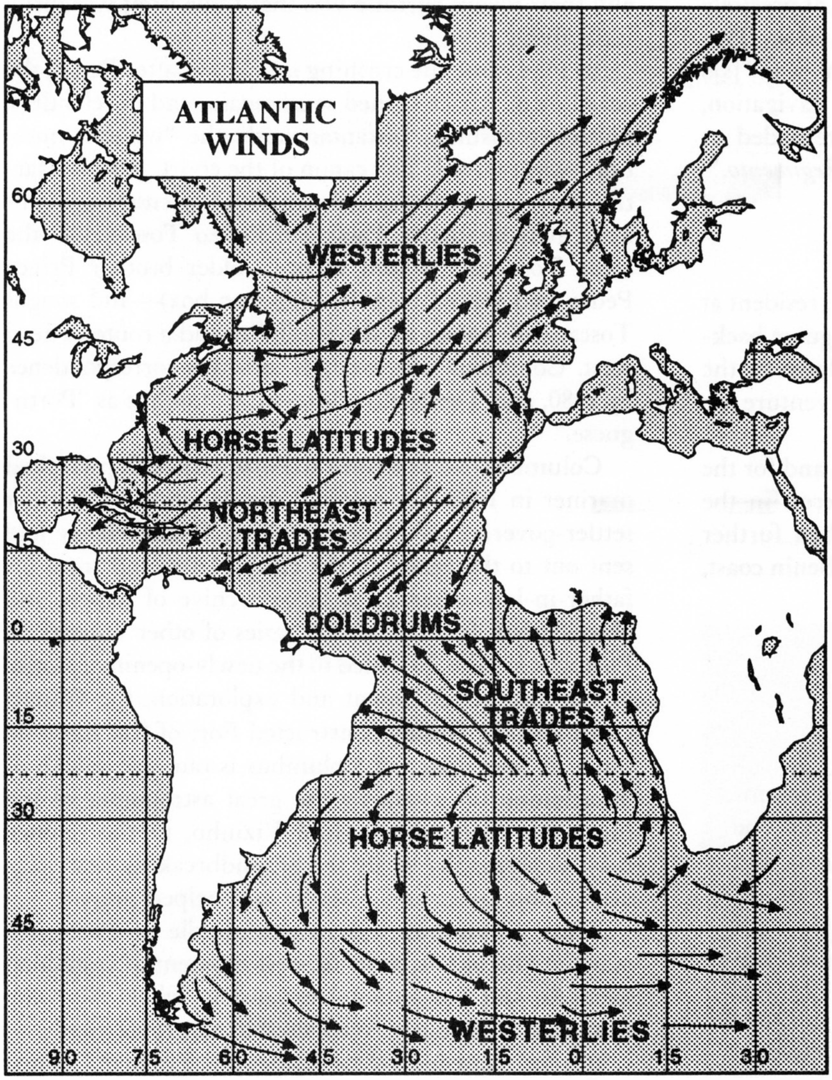
Henry's crews hit upon a unique and extraordinary solution to the problem. As the voyages probed further and further south, the captains began to set sail at an oblique angle to the contrary winds they faced heading home. They headed north and northwest. But instead of tacking a few miles, and then tacking 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).

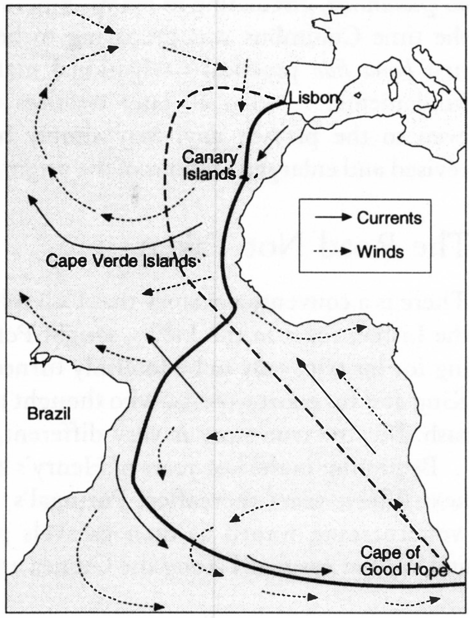
This solution was then inverted and extended into the southern hemisphere for the great breakthrough of Vasco da Gama's voyage to India in 1497. What Da Gama did—after a decade of intense Portuguese researches into the wind and ocean currents of the South Atlantic—was sail with the prevailing winds and 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.



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

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 ship-building 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).